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DEPARTMENT OF MINES
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GEOLOGICAL SURVEY
R. W. BROCK, Director

GUIDE BOOK No. 3

EXCURSIONS

in the Neighbourhood of Montreal and Ottawa

OTTAWA
GOVERNMENT PRINTING BUREAU
1913.

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Excursions in the Neighbourhood of Montreal and Ottawa

(EXCURSIONS A 6, A 7, A 8, A 10, A 11)

ISSUED BY THE GEOLOGICAL SURVEY

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CONTENTS.

PAGE.

Excursion A 6—The Morin Anorthosite Area, by F. D. Adams..... 5

Excursion A 7—The Monteregian Hills, by F. D. Adams..... 29

Excursion A 8—Mineral Deposits of the Ottawa District, by J. Stansfield..... 87

Excursion A 10—Pleistocene—Montreal, Covey Hill and Ottawa, by J. W. Goldthwait, J. Keele and W. A. Johnston..... 117

Excursion A 11—Ordovician—Montreal and Ottawa, by Percy E. Raymond..... 137

List of Illustrations..... 161



Contact of the anorthosite and Laurentian limestone.—From about 1 mile N.W. of St. Sauveur, P.Q.

EXCURSION A 6.

THE MORIN ANORTHOSITE AREA.

BY

FRANK D. ADAMS.

CONTENTS.

	PAGE.
Introduction	6
General statement concerning the anorthosite intrusions of the Canadian Shield	6
The Morin anorthosite	7
Extent and relation to the surrounding gneiss	7
Composition of the Morin anorthosite	8
Structure of the Morin anorthosite	9
Annotated guide	17
Bibliography	27

INTRODUCTION.

General Statement concerning the Anorthosite Intrusions of the Canadian Shield.

The Laurentian shield, or great Northern Protaxis of the continent of North America has an area of rather over 2,000,000 square miles (5,000,000 square kilometres) and lies almost entirely within the bounds of the Dominion of Canada.

As is well known, it consists of rocks of pre-Cambrian age, the greater part being made up of the gneisses of the Laurentian System.

Penetrating these rocks of Laurentian age, more especially along the border of the eastern portion of the Protaxis, there are great intrusions of anorthosite. These are typical plutonic intrusions, often of vast dimensions, that which occurs about the head waters of the River Saguenay having an area of not less than 5,800 square miles (13,500 square kilometres). It was from these anorthosite areas in Labrador that the minerals labradorite and hypersthene were first obtained and sent to Europe by the Moravian missionaries.

The greater number of these anorthosite intrusions are situated in very wild and inacessible districts, but one of them, the Morin anorthosite intrusion, can be reached with comparative ease, and the present excursion has been arranged with a view to enabling the members of the Congress to obtain an idea of the chief characteristics of this great anorthosite area. The various anorthosite bodies resemble one another closely in character, although in some of them certain phenomena are especially accentuated; thus, in the Labrador area to which reference has been made, the beautifully iridescent variety of labradorite ("Labrador Feldspar") is abundant. This occurs less abundantly in the other areas, and in the Morin area is scarcely ever found. The Morin anorthosite area can, be taken however, as a typical representative of the great anorthosite intrusions of Canada.

The anorthosite may be considered as a variety of gabbro in which plagioclase ("anorthose") preponderates so largely that the other components sink to the rank of accessory constituents. It may be said that usually they

do not constitute more than five per cent of the rock—the remaining 95 per cent being plagioclase which varies in composition from andesite to anorthite. The other constituents are almost invariably augite, hypersthene and ilmenite. These minerals become relatively more abundant in certain schlieren, while in most of the intrusions places can be found where the ilmenite is segregated into large masses, some of which have been worked as ores of iron.

THE MORIN ANORTHOSITE.

EXTENT AND RELATION TO THE SURROUNDING GNEISS.

The Morin anorthosite area is situated on the margin of the Laurentian protaxis 30 miles (48 kilometres) north of Montreal. It is a nearly circular mass from the south-eastern side of which, however, there is a wide apophysis extending in a southerly direction. The mass is about 37 miles (59·5 km.) in diameter and has a total area of 990 square miles (2,475 square kilometres). It cuts through the gneiss and associated rocks of the Laurentian system by which it is surrounded on all sides, except at the southern extremity of the arm-like apophysis above mentioned, where it is overlain and covered by the much more recent Palæozoic strata of the St. Lawrence valley which here are of Potsdam and Calciferous age.

The country underlain by this anorthosite, leaving out of consideration the arm-like extension above mentioned, is very hilly, but the hills seldom rise to such height as to be properly designated as mountains, and, while often rugged and precipitous, still preserve the smooth flowing contours seen everywhere in the Laurentian in this part of Canada. Between the hills are valleys or plains, generally of no great size, occupied by drift. These valleys, as well as the hill sides, are year by year being cleared of their forest growth and converted into farms that support a hardy population.

Scattered through these valleys are a great number of lakes, some of considerable size, in which North river and other streams take their rise, eventually finding their way into the Ottawa or St. Lawrence rivers.

The highest hills in the area are those about Duck lake in the township of Cartier, and those in the district

about Montagne Noire in the township of Archambault. On the whole, this anorthosite area is rather more rugged than that underlain by the surrounding gneiss.

As will be seen on consulting the accompanying map, the gneissic series through which this anorthosite has been intruded, is, so to speak, closely wrapped around the anorthosite mass, its strike for the most part following the sinuosities and curves of the contact. The most notable exception to this is along a portion of the southern boundary where the band of white crystalling limestone interstratified with the gneiss is seen to be cut out off by the anorthosite. The foliation of the gneiss is thus evidently ,in part at least, a secondary structure, induced by great pressure subsequent to the intrusion of the anorthosite. This pressure has affected the anorthosite as well, for the anorthosite, especially near the contact on the eastern side, possesses a distinct foliation coinciding in direction with that of the gneiss.

At a number of places near the limits of the area, especially about the dividing line between the rear ranges of Wexford and Chertsey, near the road to St. Donat, very large masses of orthoclase gneiss occur inclosed in the anorthosite ,and afford additional proof, if any be required, of the intrusive character of the latter.

Composition of the Morin Anorthosite.

The anorthosite throughout the area is pretty uniform in composition, the chief variations being due to a somewhat uneven distribution of the constituent minerals in the schlieren which are in places developed in the rock. The most noteworthy exception is the greater preponderance. of the iron-magnesia constituents in the extreme northwest corner of the area in consequence of which the anorthosite passes over into a gabbro.

Plagioclase, augite, hypersthene and ilmenite are by far the most important constituents. Hornblende occurs in a few places, more especially near the contact with the surrounding gneiss. Garnet, apatite, zircon and other minerals are occasionally found as accessory constituents.

The plagioclase has been found in every case where it has been examined to be labradorite and throughout the area, except where the rock has been granulated by the

action of pressure, this labradorite is filled with an infinite number of minute schillerization inclusions, which give to it a deep violet or nearly black colour, so that the massive anorthosite is always very dark.

Augite, while present in much smaller quantity than the plagioclase, is, next to it, the most abundant constituent of the rock. Rhombic pyroxene (hypersthene) is present, however, in nearly, if not quite, equal amount. Both minerals occur in grains of a pale green colour and of irregular shape. The hornblende, when found, occurs in individuals of a similar shape in intimate association with the pyroxenes and frequently forms a border around the pyroxenes. It is usually green, but is sometimes brown. Garnet very seldom occurs as a constituent of the normal anorthosite but is often found near its contact with the surrounding gneiss. It has a pale pinkish colour and is often intimately associated with grains of iron ore.

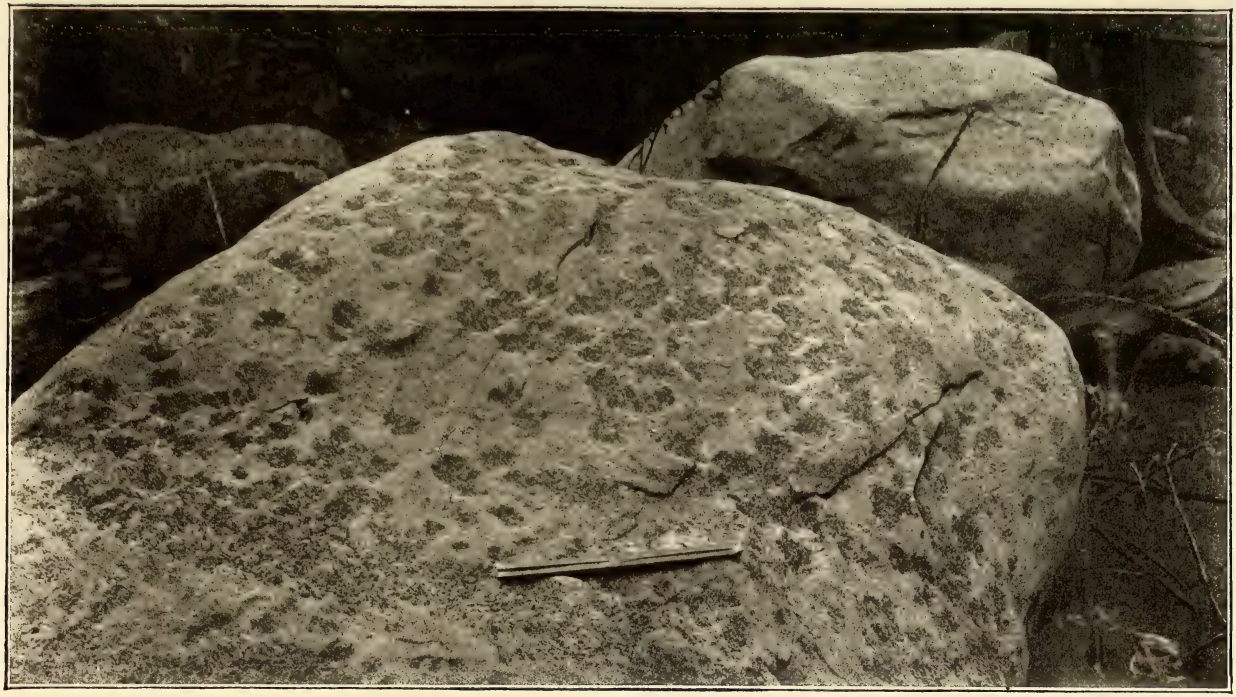
In nearly every section of anorthosite, some grains of an opaque black iron ore are seen. Those portions of the anorthosite rich in iron ore are very restricted in extent and they fade away into the normal anorthosite of the area which, as above mentioned, is very poor in iron ore.

The other constituents of the anorthosite are found but occasionally and are present in such small amount that they do not merit any especial mention.

Structure of the Morin Anorthosite.

The macroscopic structure of these anorthosites, as well as that of most of the crystalline rocks forming the Laurentian system, is best studied on the great glaciated surfaces of the *roches moutonnées*, which protrude through the drift in all directions. On a freshly fractured surface, or even on a smoothly glaciated surface which has been protected from the weather, the structure is not clearly seen; but, when the glaciated surface has been exposed during the interval which has elapsed since the disappearance of the ice, to the etching action of the weather, the structure of the rock is brought out in a wonderfully clear and striking manner. Such weathered surfaces, moreover are often square yards in extent and enable the structure of considerable masses of the rock to be determined and the relations of different structures to one another to be clearly seen.

If any large weathered surface of the anorthosite, such as is found in the *roches moutonnées* anywhere within the Morin area, be examined (leaving out of consideration for the present the arm-like extension and that part of the main area adjoining it), it will be noticed that the rock, which is coarse-grained and of a deep violet colour, has not that regularity of structure which we see in a typical granite, but presents a more or less irregular structure. This irregularity is sometimes scarcely noticeable, but is at other times striking, and is due to concentration of the bisilicates and iron ore in some parts of the rock. The portions richer in bisilicates may take the form of large irregular-shaped patches occurring at intervals through the rock, or of many small patches occurring abundantly in certain parts of the rock which elsewhere is nearly free from them. In some cases these are arranged so as to form irregular wavy streaks instead of patches. Sometimes these streaks are rudely parallel, giving a sort of strike to the rock, but in other places they are quite irregular in arrangement. Between these patches or streaks rich in bisilicates, and rather badly defined against them, are portions of the rock which are very poor in or often quite free from bisilicates. The structure is well represented in the accompanying photograph of a large anorthosite boulder on lot 5 of range IX. of the township of Chertsey. Here the iron ore and bisilicates are aggregated together in more or less rounded areas of the rock, while the remainder of the rock is almost free from iron-magnesia constituents. In those portions containing the bisilicates and iron ore, these constituents form about one-third of the rock, the rest being plagioclase. Large individuals of plagioclase, irregular in shape and which will be referred to again, occur quite abundantly in the parts of the rock free from bisilicates, but are very rarely found in the patches containing the bisilicates. With the exception of the larger individuals of plagioclase, the rock is uniform in grain throughout. The portions containing the bisilicates weather more readily than the rest of the rock, and thus leave hollows on the weathered surfaces; when the patches are elongated, as is usually the case, irregular sausage-shaped cavities usually result. In the occurrence represented in the photograph, it will be noticed that one of the masses rich in bisilicates and much larger than the others, forms a rude band across the lower portion of the



Boulder of anorthosite, range IX., lot 5, Chertsey, P.Q. Shows the segregation of the Mg-Fe minerals into certain portions of the rock.

boulder. In such cases, the bisilicate individuals are arranged with their larger axes in a direction rudely parallel to the band.

But another structure is also presented by the anothrosites. When any of the anorthosites in the area embraced by the present report are carefully examined, this streaked or irregularly banded structure is seen to be accompanied in most, if not in all cases, by a peculiar breaking or granulation of the constituent minerals of the rock. This is often beautifully displayed on the large weathered surfaces. The rock presents a peculiar brecciated structure, fragments of plagioclase and of the other constituents of the rock being imbedded in a species of groundmass made up of smaller grains. As plagioclase in most cases preponderates almost to the exclusion of the other constituents, the fragments are usually of this mineral, and, although occasionally showing an approximation to good crystalline form, they are almost invariably quire irregular or even tattered in outlines. The groundmass of smaller grains also consists of plagioclase. In some places these fragments constitute the greater part ot the rock; elsewhere they are present very sparingly and the groundmass preponderates. The larger individuals can, moreover, be frequently seen in the very act of breaking up, the several fragments having shifted their position but very slightly.

When examined under the microscope in thin sections, hardly a specimen of any coarse-grained variety can be obtained from any part of the area which does not show at least traces of this clastic or granulated structure; and if a series of specimens be studied, every step can be traced in the passage from massive anorthosite, showing the merest traces of this structure through intermediate breccia-like stages, to anorthosite consisting entirely of broken grains, or with mere remnants of the original large individuals. The three accompanying micro-photographs illustrate successive stages in this granulation. They are taken from three thin sections of anorthosite from different parts of the Morin area, photographed in polarized light between crossed nicols and equally magnified, the enlargement in each case being 18 diameters.

(a) This section, from the large exposures about five miles northwest of the village of Ste. Adèle, in the township of Morin, represents the massive anorthosite. It shows only the merest traces of granulation on the left

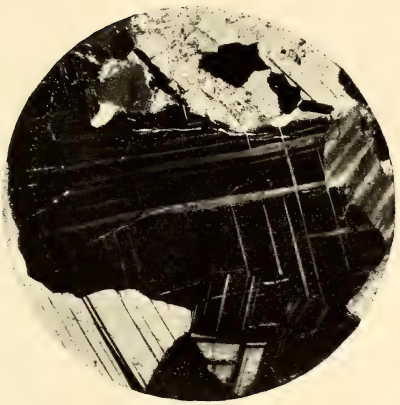


Fig. A.



Fig. B

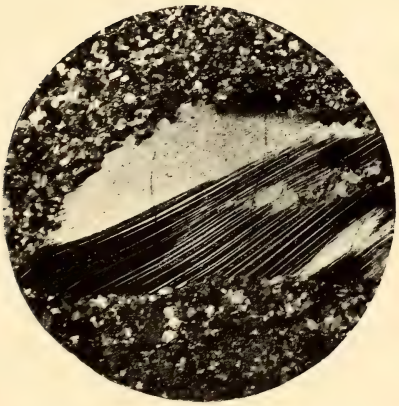


Fig. C.

Microphotographs showing the progressive granulation of the Morin anorthosite under the influence of pressure, + 18 diam:

of the field. The size and shape of the constituent individuals of plagioclase and their polysynthetic twinning are well seen. The rock is composed almost exclusively of this mineral, the individuals of which are neither bent nor twisted, and no strain-shadows are to be observed.

(b) In this section, which was prepared from a specimen collected about three and a half miles north-east of White Lake, in the front of the township of Chilton, a distinct breaking or granulation of the plagioclase can be observed, especially in the lower portion of the slide, while the same process can be elsewhere seen, though not so well marked. The large plagioclase individuals no longer meet along clear well defined boundary lines, but are irregular in shape, cracked, and separated from one another by a mosaic of broken grains. Strain-shadows, twisted twin lamellae and other evidences of pressure are well shown. The rock shows no distinct foliation or banding.

(c) The third section shows the appearance presented by a highly granulated variety of the anorthosite under the microscope. This specimen was obtained from the arm-like extension of the anorthosite mass before mentioned near its western contact with the gneiss, on range XI of the township of Rawdon. In this section, about one-half of the field is occupied by broken grains of plagioclase, while in the middle is a large plagioclase individual in process of destruction. A line of granulated material is being developed in a longitudinal direction through the large crystal, making, as is usual, an angle of about 20° with the lines of twinning, and which, if continued, would cut it in two; while little fragments of the plagioclase can be seen about its edge in the very act of breaking off—first a strain-shadow (excellently seen on the upper edge of the large individual) appearing, then a curved crack extending in from the edge of the crystal, and finally the breaking away of the small piece of the mineral, leaving an irregular indentation. The appearance is precisely that which the mineral would present if little pieces were being broken off the edge with a pair of small pincers. The strain having been relieved by fracture, all evidence of pressure disappears in the broken grain. If a thin section were composed of broken grains alone, it would be impossible in most cases to determine that these had resulted from the breaking down of larger individuals. This rock is

excellently foliated, owing to the finely granulated material, which results from the breaking up of each large individual, arranging itself in the shape of a very flat lens about the crystals remnant from which it was derived. This lens, of course, lies in a plane at right angles to the pressure, and in section appears as a long slender tail of broken grains extending from the remnant in either direction.

The pyroxenes, rhombic or monoclinic, when present in the rock, undergo a precisely similar process of granulation with the formation of similar tails of broken grains.

A very remarkable fact in this connection is that the large crystal fragments of plagioclase have a deep violet colour, while the granulated plagioclase is white. This contrast is excellently seen either on the weathered surface or when a thin section is placed on a sheet of white paper, and is due to the fact that the minute dark-coloured or black inclusions, which abound in the large individuals. are absent in the broken material. They seem to have aggregated themselves together into little grains of titanic iron ore, which occur in the granulated plagioclase, but which are absent in the large individuals. So distinctive is this contrast of colour, that when a thin section containing plagioclase in both forms is placed under the microscope, it is possible at once to predict from the colour alone, just what portions will show granulation and what portions will not, before the actual structure has been revealed by the agency of polarized light. This might seem at first sight to indicate a recrystallization in the case of the granulated portions of the plagioclase, but the facts do not seem to support this supposition. At any rate the feldspar does not alter in composition during the process of granulation, but merely breaks, and becomes lighter in colour through the loss of the dark inclusions.

In the Morin anorthosite, the most granulated varieties are found near the sides of the intrusion, especially on the east side, as if the pressure had been exerted from that direction, but more or less distinct evidences of granulation can be seen throughout the entire area. The white granulated anorthosite forms the greater part of the arm-like extension of the Morin mass, protruding through the drift in all directions in the form of hundreds of smooth white hummocks and giving a striking appearance to the landscape, as, for instance, about the village of New Glasgow. Further, it can be observed that everywhere

in this arm-like extension and in almost all its occurrences elsewhere, this white granulated anorthosite is more or less distinctly foliated, owing to the arrangement of the bisilicates and iron ores in more or less distinctly parallel lines or streaks. It is often quite evident that these are nothing more than the rounded patches, rich in bisilicates, described for the massive anorthosite and which, owing to a movement in the rock, have been drawn out in one direction. The irregular-shaped patches, differing greatly in size of grain, that have been described as occuring in the massive rock, are also represented here by elongated streaks of similar character. This foliation is best seen where bisilicates and iron ore are comparatively abundant. When, as is sometimes the case, the rock is almost free from these constituents and all the plagioclase fragments have been destroyed, it assumes a nearly uniform granular character, and no trace of foliation can be observed. Along the western border of the arm, the strike is exceedingly regular and remarkably well developed, as at New Glasgow, but is especially well seen along the same contact further north on range XI of the township of Rawdon, on the road between the villages of Chertsey and Rawdon. At this latter locality the rock has a remarkably regular schistose structure, due to the alternation of thin layers of pure plagioclase with still thinner ones of pyroxene. The pyroxene bands might more properly be called leaves, as they are very thin, being frequently represented by mere parallel lines in transverse sections. When examined under the microscope, in thin sections or weathered surfaces, both they and the plagioclase layers are found to contain small cores or remnants of large individuals with tails of grains extending from them in either direction as before described. These give rise to the perfect foliation and the progress of granulation is seen in an astonishingly perfect manner, the cores being in the very act of breaking up.

The question of the origin of the several structures described next presents itself. There is every reason to believe that those structures which have been described as occurring in the massive anorthosite, namely, the irregularity in size of grain and the more or less irregular distribution of the several constituents through the rock, are original structures. These irregularities, frequently seen in intrusive rocks, are certainly not the results of

pressure; and the circumstance that the streaks or irregular bands, when present in the otherwise massive rock, assume no definite direction, but twist about as if owing to the movements of the rock while in a pasty condition, indicates that they have been produced by movements before the rock became solid. The unequal distribution of the constituent minerals in the rock, must have resulted either from irregularities in the composition of the original magma, or from processes of segregation at work in the magma during cooling and crystallization.

On the other hand, the granulation of the coarsely crystalline massive anorthosite, usually with concomitant development of a more or less distinctly foliated or schistose structure in the way described, is undoubtedly due to movements in the rock, resulting from pressure which acted subsequent to or possibly during the last stages of its solidification, for, as has been shown, the granulation begins to make its appearance in the massive crystalline rock itself. Under the influence of pressure, the massive rock gradually gave way, and the movements resulted in granulation. Moreover, wherever these movements continued longest or were most intense, this granulation became most complete, until finally the last remnants of the larger individuals disappeared, and in the case of a pure anorthosite, a more or less evenly granular rock resulted. In the anorthosite, however, the remnants of larger individuals are seldom or never entirely absent, and over the greater part of the area the amount of interstitial material is quite small.

ANNOTATED GUIDE.

Miles and kilometres.

0·0 **Montreal—Place Viger Station**—Altitude, 58·49 ft. (17·8 m.).

5·1 m. **Mile End**—Altitude 225 ft. (68·5 m.)

8·2 km. Leaving Place Viger station, the railway passes along the north bank of the St. Lawrence river and then through the western portion of the city, which is underlain by the limestones of the Trenton formation (Ordovician) which are here about 600 feet, thick. The intrusive mass of Mount Royal (one of the Monteregian hills) composed of essexite and nepheline

Miles and kilometres.

syenite, is seen on the left. On its steep slopes are wave-cut terraces, with fossiliferous marine clays and other evidences of the submergence of this portion of the country in post-Glacial times. About Mile End are large quarries from which stone for building purposes and for the production of lime is obtained. The grey limestone of which Montreal is largely built, is obtained chiefly from these quarries.

These Trenton limestones are highly fossiliferous; over 80 specimens of marine invertebrata have been described from them, including *Lingula quadrata*, *Plectambonites sericeus*, *Ctenodonta nasuta*, etc.

The plain traversed by the railway is a portion of the great plain of the St. Lawrence lowlands, which stretches away to the north as far as the margin of the Canadian Shield, which here is 30 miles distant. The Ordovician rocks of the plain are covered by deposits of Pleistocene age, consisting of boulder clay overlain by the Leda clay and Saxicava sand, both of which are in many localities filled with marine shells. The plain, which is very fertile and supports a large farming population, gradually rises to the north and at the margin of the Canadian Shield has an elevation of about 300 feet. (91·4 m.).

Three quarters of a mile beyond Mile End the Trenton is succeeded by the conformably underlying limestones of the Chazy.

9·9 m.
15·9 km. **Bordeaux**—Alt. 75 ft. (22·8 m.) Here the train crosses the Back river, or Riviére-des-Prairies, a branch of the Ottawa river which flows around the north side of the Island of Montreal and enters the St. Lawrence a few miles farther to the east.

The river here runs very rapidly, forming the Sault-au-Recollet, called after Nicholas Veil, a Recollet priest who was drowned here by the Huron Indians in 1626.

10·3 m.
16·6 km. **Parc Laval.**

12·8 m.
20·4 km. **St. Martin's Junction**—Alt 110 ft. (30·8 m.). The line for Quebec leaves here.

17·3 m. 27·8 km. **Ste. Rose**—Alt. 85 ft. (25·9 m.). Just before reaching this point the Chazy limestone is succeeded by the underlying dolomitic limestones of the Calciferous. The line crosses the Riviére des Milles Iles, another branch of the Ottawa, which to the east becomes confluent with Back river before the latter reaches the St. Lawrence.

18·0 m. 29·0 km. **Rosemere**—Alt. 91 ft. (27·7 m.).

20·0 m. 32·2 km. **Ste. Thérèse**—Alt. 120 ft. (36·6 m.). Lines leave here for Ottawa and St. Eustache.

27·2 m. 43·8 km. **St. Janvier**—Alt. 217 ft. (66·1 m.).

31·7 m. 51·0 km. **Montfort Junction** Alt. 262 ft. (79·8 m.). The Canadian Northern railway crosses.

33·2 m. 53·4 km. **St. Jérôme**—Alt. 308 ft. (93·9 m.) Just before arriving at St. Jérôme the margin of the Laurentian protaxis is reached. The Palæozoic probably comes against the Laurentian here along a line of fault. At this point the abrupt rise of the Laurentian plateau is not so distinct as elsewhere in this district, owing to the fact that the North river here issues from the Laurentian country, running in a rather wide valley up which the railway takes its course. At St. Jérôme, however, the character of the country undergoes an abrupt change, the rough and broken surface of a gabbro intrusion in the Laurentian succeeding the level surface of the Palæozoic plain.

41·9 m. 67·4 km. **Shawbridge**—Alt. 599 ft. (186·6 m.). The country rises and becomes rolling, showing the *roche moutonnèe* surfaces of the Laurentian protaxis. Cliffs of gneiss are seen to the right. The railroad follows the valley of North river which is filled with drift and shows well defined terraces on either side of the stream. Fine sections are seen at intervals.

46·1 m. 74·2 km. **Piedmont**—Alt. 552 ft. (168·2 m.). The Laurentian gneisses are here cut through by the Morin anorthosite. The actual contact, however, is concealed by heavy drift.

Miles and kilometres.

The country continues to rise and becomes more rugged. Rugged hills of anorthosite with scarred faces are seen on either side.

49·1 m.
79·0 km.

Ste. Adele.

53·7 m.
86·4 km.

Ste. Marguerite—Alt. 637 ft. (194.2 m.) A mile and a quarter beyond Ste. Marguerite the railroad passes through a heavy cut in deep violet-coloured anorthosite, the walls of which as shown in the accomanying illustration, rise to a height of 50 feet (15·2 m.) on either side.

From the railway track at the entrance to this cut a typical Laurentian landscape is seen Fine glaciated hills of anorthosite are observed as far as the eye can reach, many of them still possessing their original forest covering. The North river runs through the valley below.

This point is well within the Morin anorthosite intrusion, being six miles from the nearest point on its margin.

The rock is composed almost exclusively of labradorite, either reddish-violet or greenish in colour. The only other constituent present is ilmenite, of which an occasional small individual is seen in thin sections. The plagioclase is beautifully twinned and is filled with very minute schillerization products, which are the cause of its dark colour. The rock is practically free from all evidences of pressure. The anorthosite in the cutting is coarse in grain and massive, and occasionally holds larger irregular-shaped individuals of labradorite, having cleavage surfaces measuring as much as three inches (7·6 centimetres) across. It may be taken as typical of the anorthosite which forms the greater part of the intrusion and all the central portion of the stock.

A quarter of a mile east of this cutting, and one mile from the Ste. Marguerite station, a rusty-weathering, garnetiferous variety of the anorthosite is exposed on the north side of the track. This contains, in addition to labradorite, a considerable amount of a pale green augite and ilmenite. It shows in a striking manner the



Cliffs of massive anorthosite in railway cutting a mile and a quarter northwest of Ste. Marguerite.

Miles and kilometres.

action of pressure on the rock, the larger individuals of the constituent minerals being twisted, broken and granulated. This occurrence is on a line of movement in the anorthosite.

53·7 m. **Ste. Marguerite**—Alt. 900 ft. (274·3 m.)

86·4 km. **St. Jérôme**—Alt. 308 ft. (93·9 m.) The
74·2 m. train now returns to St. Jerome. A small
119·4 km. isolated area of gabbro occurs in the Laurentian gneiss at this locality. It is much richer in iron magnesia constituents than the normal anorthosite of the Morin area. It is well exposed on either side of the railway track a few hundred yards south of the Canadian Pacific Railway station.

Here the rock is fine in grain, usually foliated and weathers brownish-grey. In some places it possesses a more or less distinctly banded structure, due to the alternation of portions rather rich in bisilicates with others consisting almost entirely of plagioclase. Individuals of dark coloured plagioclase, usually small in size, but sometimes as much as six inches in length, are abundant in places. They are frequently curved or twisted, and are usually without good crystalline outlines.

Under the microscope, the rock is seen to be composed essentially of plagioclase and pyroxene the former preponderating largely, with hornblende, biotite, garnet, iron ore and pyrite as accessory constituents, and with a few grains of quartz, calcite, chlorite and apatite. The pyroxene is light green in colour, and is for the most part augite, which is often decomposed to calcite and chlorite. Some of it, however, is trichroic, in red, yellow and green tints, and is probably hypersthene. The hornblende, which is green in colour, and the biotite are present in but very small amounts. The garnet is pink and perfectly isotropic; it is often well crystallized and usually has some approximation to good crystalline form. It is generally associated with the iron ore which is often present in considerable amount. As in certain parts of the Morin

Miles and kilometres.

anorthosite, there are probably two kinds of iron ore associated with one another, one rich in titanium and one poor in, or free from, that element. A portion of it is titanic iron ore, for leucoxene often appears as a decomposition product. The calcite is always present as a



Anorthosite from New Glasgow, P.Q. Microphotograph between crossed nicols. × 28 diam.

decomposition product and the quartz, which is found in very small amount, is associated with the bisilicates, and may also be secondary.

The rock in its present form probably represents an advanced stage of granulation, for although twisted grains and strain-shadows

Miles and kilometres.

are not very common, these, as has been shown in describing the Morin anorthosite, are not distinct when the granulation is complete. On the other hand, the large remnants of plagioclase, which occur abundantly in many places, point very strongly to an advanced stage of crushing.

This gabbro intrusion is surrounded by a zone of rock intermediate in character between the gabbro and the surrounding gneiss and which probably represents a border facies of the gabbro. This gabbro is cut by a few small black dykes of post-Archaean age.

74·2 m. 119·4 km. **St. Jérôme**—Alt. 308 ft. (93·9 m.)

77·5 m. 124·7 km. **Montfort Junction**—

80·3 m. 129·2 km. **Paisley**—

83·1 ,m 133·7 km. **Ste. Sophie**—Alt. 251 ft. (76·5 m.)

85·0 m. 136·8 km. **New Glasgow**—Alt. 240 ft. (73·1 m.)

This village of New Glasgow is situtaed near the western side of the long arm-like apophysis of the anorthosite intrusion referred to before. Here the anorthosite, under the great pressure exerted upon it from the east, has undergone great deformation. It is much finer in grain than the anorthosite at Ste. Marguerite, thoroughly granulated and has a distinct foliation. As already explained, the anorthosite loses its colour under these conditions and whenever the iron magnesia minerals are sufficiently abundant to make the structure evident, the rock is seen to be distinctly foliated. The roches moutonnées of white anorthosite, which protrude through the drift in all directions, form a striking feature of the landscape.

These are well seen along the road which runs north from the railway station and follows

Miles and kilometres.

the course of the River L'Achigan. Immediately to the south of the road, at a point two miles from New Glasgow, anorthosite has been quarried for paving sets at two places. The first of these is 160 yards from the road. Here the anorthosite is seen to possess a distinct foliation marked by little lines of the iron magnesia constituents and garnet.

Four fine-grained, black dykes of diabase of much later date, the largest of which is four feet wide, here cut the anorthosite transverse to its foliation. The iron magnesia constituents in the anorthosite are hornblende and augite. The former mineral, as has been already mentioned, is found in the Morin anorthosite only in a few places near the border of the mass. The rock is very fresh and in addition to being granulated has probably been recrystallized, in part at least, under the intense movement to which it has been subjected.

Six hundred yards from the road is a quarry from which over half a million paving sets were taken for use along the harbour front in Montreal. The anorthosite here is pale grey in colour and weathers white. Occasional dashes of dark bisilicates can be seen as well as occasional rennants of larger phenocrysts or individuals which have escaped complete granulation. Like the anorthosite last mentioned, it has probably undergone a considerable amount of recrystallization. The iron-magnesia constituents present are hornblende, augite and hypersthene.

85·0 136·8 km. **New Glasgow**—Alt. 240 ft. (73·1 m.) To the west of New Glasgow excellent exposures of the white foliated anorthosite are seen along the line of the Canadian Northern railway. The fine waterfall on the outskirts of the village is formed by L'Achigan river cascading down over a great exposure of this rock. A microphotograph of a thin section of this rock between crossed nicols is shown in the accompanying plate (p. 23).



Exposures of white anorthosite. Falls of the river L'Achigan, New Glasgow, P.Q.

Miles and kilometres.

A short distance west of L'Achigan river the anorthosite is cut by a great dyke of a nearly black gabbro which can be followed to the north for nine miles. It is strikingly jointed and possesses a very marked streaked or foliated structure parallel to its length. This direction coincides with that of the foliation of the intruded anorthosite. This gabbro holds inclusions of the anorthosite and further north sends a long apophysis into the anorthosite, cutting across the strike of the latter. It is very basic in character and under the microscope displays a most remarkable cataclastic structure, larger twisted remants of the constituent minerals being embedded in a mass of finely granulated material derived from the breaking down of the larger individuals of the several constituent minerals.

The train now returns to Montreal via St. Jerome.

86·9 m. 139·8 km. **Ste. Sophie**—Alt. 251 ft. (76·5 m.) Exposures of a typical orthoclase gneiss of the Laurentian, as well as a small band of limestone belonging to the Grenville series, are seen where the road running west from Ste. Sophie crosses a little stream near the outskirts of the village.

95·8 m. 154·2 km. **St. Jérôme**—Alt. 308 ft. (93·9 m.)

129·0 m. 207·6 km. **Montreal**—

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EXCURSION A 7.

THE MONTEREGIAN HILLS.

BY

FRANK D. ADAMS.

CONTENTS.

	PAGE.
Introduction	30
The geology of Mount Royal	33
Essexite	37
Nepheline syenite	38
Dyke rocks	42
Bostonite	44
Tinguaite	44
Nepheline aplite	45
Analcite dykes	45
Monchiquite	45
Fourchite	47
Camptonite	47
Alnoite	47
Annotated guide	49
The geology of St. Helen's island	55
Mount Johnson	60
Annotated guide	60
Geology of Mount Johnson	61
Pulaskite	64
Transition rock	67
Essexite	69
Dykes	75
Structure	75
Bibliography of the Monteregian hills	79

INTRODUCTION.

In the Province of Quebec, between the enormous expanse of the Laurentian highlands to the northwest, constituting the "Canadian Shield," and the disturbed and folded tract of country which marks the Appalachian uplift, there is a great plain underlain by nearly horizontal rocks of lower Palæozoic age. This plain, while really showing slight differences of level from place to place, seems to the casual observer perfectly flat. Its surface is mantled with a fertile soil consisting of drift redistributed upon its surface by the sea, which covered it at the close of the Glacial times. The uniform expanse of this plain, however, is broken by several isolated hills composed of igneous rocks, which rise abruptly from it and which constitute very striking features of the landscape. It was at the foot of one of these hills rising by the side of the River St. Lawrence, and which he named Mount Royal, that Jacques Cartier on his first visit found the Indian encampment of Hochelaga, the site of which is now overspread by the city of Montreal.

From the top of Mount Royal the other hills referred to can all be seen rising from the plain to the east; while to the north the plain stretches away unbroken to the foot of the Laurentian plateau.

As has been remarked by Sir Archibald Geikie in his Text-Book of Geology: "The word 'mountain' is, properly speaking, not a scientific term. It includes many forms of ground utterly different from each other in size, shape, structure and origin. In a really mountainous country, the word would be restricted to the loftier masses of ground, while such a word as 'hill' would be given to the lesser heights. But in a region of low or gently undulating land, where any conspicuous eminence becomes important, the term 'mountain' is lavishly used. In eastern America this habit has been indulged in to such an extent that what are, so to speak, mere hummocks in the general landscape are dignified by the name of mountain."

The hills under consideration, while by no means "mere hummocks", being situated in such a country of low relief, seem to be higher than they really are and are always referred to locally as "mountains."

St. Bruno. Beloeil. Rougemont. Mt. Johnson.



View of the Monteregian Hills from Mount Royal. In the foreground the city of Montreal. In the middle distance the River St. Lawrence with St. Helen Island. (Reproduced with the permission of Messrs. William Notman & Son).

32224—p. 31.

These mountains, whose positions are shown on the accompanying map, are eight in number, their names and their height above sea level being as follows:

Mount Royal	769·6	feet.
Montarville or St. Bruno	715	feet (O'Neill).
Belœil	1,437	" (Leroy)
Rougemont	1,250	"
Yamaska	1,470	" (Young).
Shefford	1,725	"
Brome	1,755	"
Mount Johnson or Monnoir	875	"

They have been called the Monteregian Hills from Mount Royal ("Mons Regius"), which is the best known member of the group and may be taken as their type.

Brome mountain is by far the largest member of the group, having an area of 30 square miles. Shefford comes next in size, having an area of rather less than nine square miles; while Mount Johnson, which is very much smaller than any of the others, has an area of only ·422 of one square mile.

Of these eight, the first six, as Logan* notes, "stand pretty nearly in a straight line." running approximately east and west, Mount Royal being the most westerly, and the others following in the order in which they are enumerated above, until Shefford mountain, the most easterly member of the series, is reached. Mount Johnson and Brome mountain lie on a line parallel to them, a short distance to the south, Rougemont being the nearest neighbour to Mount Johnson and Brome mountain immediately south of Shefford. It is highly probable, in view of this distribution, that these ancient volcanic mountains are, as is usual in such occurrences, arranged along some line or lines of weakness or deep-seated fracture. The "pretty nearly straight line" referred to by Logan, on which the first six mountains of the group are situated, must be considered either as a single line with a rather sharp curve in the middle or as made up of two shorter straight lines, each with three mountains, diverging from one another at an angle of about 30°, with Montarville at the point of intersection. Mount Johnson and Brome mountain might then be considered as situated on short subsidiary fractures.

*Geology of Canada, p. 9.

The distance from Brome mountain the most easterly member of the Monteregian Hills, to Mount Royal the most westerly, is 50 miles (80 km.). For a few miles to the east and west of these mountains respectively, however, evidences of the igneous activity of the system are manifested in the occurrence of occasional dykes or small stocks of the consanguineous rocks of the series, the extreme easterly representative of these being a little stock exposed about a mile and a half east of Eastman, on the line of the Canadian Pacific railway, and the most westerly being a series of dykes and a small stock at La Trappe, on the Lake of Two Mountains. Similarly, the most northerly extension is represented by a sheet intercalated between strata of the Chazy limestone in the bed of the Little river, near St. Lin, 15 miles (24 km.) north of St. Lin Junction. It is difficult to say just how far to the south the last evidences of the Monteregian activity are found, but scattered dykes of bostonite, camptonite and monchiquite have been described by Kemp and Marsters from the shores of Lake Champlain (out of which flows the River Richelieu), to a distance of 90 miles (145 km.) or more south of Mount Johnson.

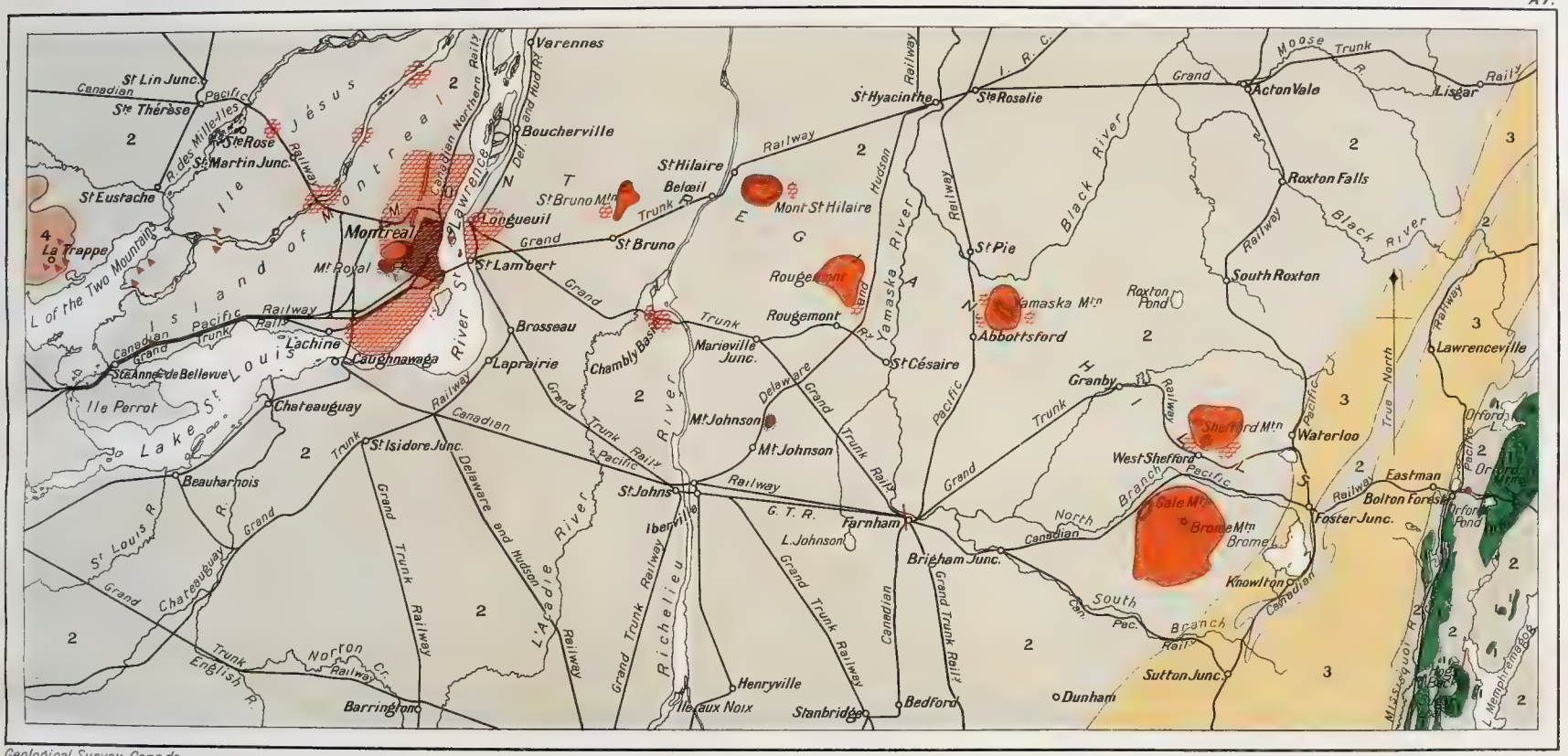
The accompanying map embraces the entire region affected by the intrusions of the Monteregian Hills, so far as its eastern and western extension is concerned: while beyond the limits of the map, to the north and south, the occurence of scattered dykes occur as has been noted, which, from their petrographical character are believed to be related to these intrusions.

The Monteregian Hills are a series of ancient plutonic intrusions. Some of them (e.g. Brome mountain) are apparently denuded laccoliths, one of them (Mount Johnson) is a typical neck or pipe, and it is probable that some, if not all, of them, represent the substructures of volcanoes which at one time were in active eruption in this region.

It is impossible to determine accurately the date of these intrusions. In the case of Mount Royal, however, inclusions of Lower Devonian limestone are found in the intruded rock, so that the intrusions forming the mountain are later than Lower Devonian time.

Since Dresser by another line of evidence, has shown that the intrusion of Mount Shefford probably took place before late Carboniferous time, the Monteregian intrusions probably date back to the late Devonian or early Carboniferous period.





Legend

- 4 — Laurentian
- 3 — Pre-Cambrian
- 2 — Palæozoic
- Diorites, serpentines, etc. (Eastern intrusive series older than the Montereglan Hills
- Montereglan Hills (Nepheline syenite, Essexite, etc.)
- Consanguineous dyke rocks of the Montereglan Hills
- Consanguineous dyke rocks of the Montereglan Hills, holding many inclusions (Breccias)

Geological Survey, Canada

Montereglan Hills

Miles 0 10 20

Kilometres 0 10 20 30

t must be noted that while six of these mountains .rom the horizontal strata of the plain, the two most -terly members of the group, namely Shefford and Brome, s still to the west of the axis of that range, lie well in the folded belt of the Appalachians, although, to the extensive denudation from which the region ffered, this folding has had but little influence on cal topography. About La Trappe, at the extreme esterly extension of the Monteregian area, the dykes of the series cut rocks of Laurentian age, which here form an outlier of the great Laurentian protaxis on the north.

The Monteregian Hills form an exceptionally distinct and well marked petrographical province, being composed of consanguineous rocks of very interesting and rather unusual type. These are characterized by a high content of alkali and in the main intrusion of almost every mountain two distinct types are found associated with one another, representing the products of the differentiation of the original magma.

These are—

(a) Nepheline syenite, in some cases replaced by or associated with pulaskite, tawite, akerite or nordmarkite.

(b) Essexite, in some cases represented by theralite, yamaskite, rougemontite, or rouvillite.

It may be mentioned that yamaskite is a very basic rock type characterized by a great predominance of pyroxene, basaltic hornblende and ilmenite, with about two per cent of anorthite. Rougemontite consists largely of anorthite with pyroxene as the only important ferro-magnesian constituent. Rouvillite is a highly feldspathic variety of theralite.

GEOLOGY OF MOUNT ROYAL.

Mount Royal consists of a body of intrusive plutonic rock penetrating the nearly horizontal limestone of the Trenton formation (Ordovician). It consists of two main intrusions composed of sexite and nepheline syenite respectively, of which nepheline syenite is the later. followed by a swarm of kes and sheets of consanguineous rocks which cut r only the main intrusions, but also penetrate the surro ding limestones in all directions. The intrusive rock in e places tilts up the limestones while elsewhere about t e mountain these maintain their

horizontal attitude. The intrusion may be essentially laccolitic in character, or it may represent the plutonic basis of a volcano. The erosion has been so long continued that it has been impossible as yet to reach a definite conclusion on this point.

The greater part of the plain through which the mountain rises, and which is underlaid by Ordovician strata, is mantled by drift which also covers the slopes of the mountain. This drift, and in some places the underlying rock, has been terraced by a series of well defined beaches, which mark the successive stages of the retreat of the sea at the close of the Glacial age.

The City of Montreal is built upon these drift deposits, and lies upon the slopes of Mount Royal and upon the plain about its foot. The development of the city was largely influenced by the position of the main beaches above mentioned.

At a number of places on the slopes of Mount Royal and in its vicinity there are remarkable developments of igneous breccia. This has as a matrix one or other of the dyke rocks of the series, while the included fragments consist in part of the Trenton limestone, often associated with fragments of the other underlying stratified rocks traversed by the dykes in their upward passage. These fragments are frequently so numerous that thay constitute a large part of the whole mass. Perhaps the most remarkable of these breccias is that which occurs on St. Helen's island in the harbour of Montreal, and which is unique among these occurrences in that it contains fragments of rocks which are more recent in age than any of the sedimentary strata now found in the district.

At the present time a tunnel, about three and a half miles in length, is being driven through Mount Royal by the Canadian Northern Railway, in order to gain an entrance from the westward to their proposed terminals in the vicinity of the corner of Dorchester and Ste.Monique streets, in the city of Montreal. It has afforded an excellent opportunity of studying the distribution of dykes, sheets, etc,. as well as fresher specimens of many of the rock types of the district. Already about two miles and a half of the sub-heading have been driven. The profile accompanying this guide book (p. 36) shows the geological section which the tunnel is penetrating. As may be seen from an examination of the geological map upon which the position of

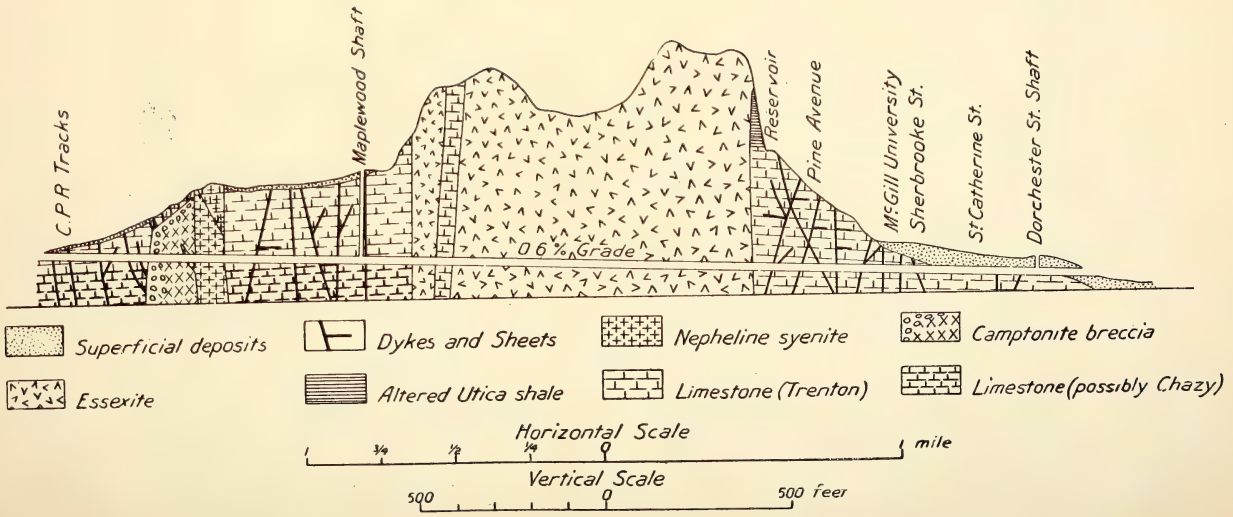


View of Mount Royal from the south (Reproduced with the permission of Messrs. William Notman & Son.)

32224—3½



Breccia with camptonite matrix. Rockland avenue, Outremont, Montreal.



Section through Mount Royal along the line of the Canadian Northern Railway tunnel.

the tunnel is indicated, the presence of the column of limestone which appears to be within the main body of essexite of Mount Royal is due to an embayment in the periphery of the latter.

The Essexite.

The essexite exposed near the Lookout may be taken as representing the main body of the essexite intrusion of Mount Royal. It is coarse in grain, but varies somewhat in texture from place to place. It is composed essentially of pyroxene and hornblende with plagioclase and a little nepheline. The other minerals, which are present as accessory constituents, are olivine, biotite, sodalite (or nosean), orthoclase, apatite, iron ores, pyrite, sphene and zircon.

The plagioclase and nepheline are always distinctly subordinate in amount, the rock consisting predominantly of augite and hornblende. In certain parts of the mountain, olivine becomes relatively much more abundant and the rock passes into an olivine-essexite (see page 38).

The olivine, augite and hornblende have a marked tendency to assume idiomorphic development, some varieties of the essexite consisting of well defined crystals of these minerals embedded in a ground mass consisting chiefly of small laths of plagioclase. The augite and hornblende in a certain rare varieties of the rock are developed as long narrow rod-like individuals, lying in parallel position and thus giving to the rock a peculiar and striking appearance.

Pyroxene is the most abundant constituent in most varieties of the rock. It is of a purplish colour and frequently holds many minute black inclusions. Twinning is common and the individuals occasionally display an hour-glass structure.

Hornblende usually ranks next in abundance. It is deep brown in colour, strongly pleochroic, and frequently occurs intergrown with the pyroxene or as a border about it. The hornblende separated from the coarse-grained essexite occurring in the Protestant cemetery was analysed by Prof. B. J. Harrington, with the results set forth in column III, page 39. As will be seen, it belongs to the class of basaltic hornblendes and is similar in composition to the hornblende occurring in the essexite of Mount Johnson.

The plagioclase is an acid labradorite. It is excellently twinned according to the albite and carlsbad laws. The zonal structure occasionally displayed by the mineral shows that there is a certain variation in composition, even within the same individual. In many specimens of the rock the plagioclase is clearly older than the ferro-magnesian constituents, since it penetrates or is enclosed in the individuals of these latter minerals. In some cases it even occurs as perfect crystals entirely embedded in the iron ore.

Nepheline as has been mentioned, is present only in relatively subordinate amount. It is allotriomorphic and occurs in the interspaces between the feldspar individuals.

The other minerals present as accessory constituents, do not here require further mention.

The analysis of two specimens of the essexite from Mount Royal are given below under No. I and No. II page 39.

The first (No. I) is found in an exposure 100 yards (91 m.)) west of the Lookout; it is a variety containing a relatively large proportion of the salic constituents, although in it as in all the essexite of the mountain, the iron magnesia constituents preponderate very largely.

The second (No. II) is an olivine-rich variety of the essexite from the Côte des Neiges road, near the reservoir. This contains scarcely any salic constituents. In the Quantitative System of classification it occupies a hitherto unnamed subrang. Its position is as follows:—

Class IV. Dofemane.
Order 2. Scotare.
Section 2. Paoliare.
Subrang 2. Montrealose.

At the suggestion of Dr. H. S. Washington this has been called montrealose, and the rock montrealite. In composition it resembles somewhat closely the essexite from Brandberg, Kirchspiel Gran, Norway.

These may be taken as two typical varieties of essexite representing the intrusion as a whole.

	I Essexite near Look-out, Mount Royal. (M. F. Connor).	II Olivine essexite (Montrealite) Côte des Neiges Rd. Mount Royal (M. F. Connor).	III Hornblende in essexite. Protestant Cemetery, Mount Royal (B. J. Harrington).
SiO_2	43·10	44·66	39·23
TiO_2	2·80	2·27	4·53
Al_2O_3	13·94	9·64	14·38
Fe_2O_3	4·92	4·98	2·92
FeO	6·93	6·65	8·56
MnO	·14	·19	·65
CaO	14·65	13·11	11·70
BaO	·03	none.	
SrO	·03	·03	
MgO	8·86	12·83	13·01
Na_2O	2·50	2·07	3·05
K_2O	·89	1·17	·98
P_2O_5	·27	·24	
CO_2	·64	·37	
Cl	trace.	·07	
SO_3	none.		
FeS_2	S=22	·22	
Fe_7S_8		trace.	
H_2O (above 110° C.)	·55	·79	
H_2O (at 110° C.)	·15	·11	·36
	100·62	99·40	99·37

The Nepheline Syenite.

This rock is much lighter in colour than the essexite, being relatively richer in salic constituents. It is usually grey in colour and of medium grain. It is, furthermore, nearly uniform in size of grain and does not display the rapid variations in texture which often characterize the essexite.

It is composed essentially of orthoclase, nepheline and hornblende; pyroxene and mica are often associated with the hornblende; while the following minerals have

been found as accessory constituents: albite, anorthoclase, microcline, nosean, sodalite, apatite, sphene, zircon, garnet, fluorite, astrophyllite, mosandrite (?), ainigmatite (?) allanite (?). Of these accessory constituents, nosean, sphene and garnet are very common. An analysis of this rock from the Corporation quarry is given on p. 41 under No. I.

Orthoclase presents the usual characteristics of the species, and is frequently somewhat turbid from the presence of minute inclusions. It occurs in individuals elongated parallel to the clinopinacoid and is intimately associated and at times intergrown with the other feldspars which occur as accessory constituents.

Nepheline is so abundant that the rock gelatinizes readily when powdered and heated with dilute hydrochloric acid. It often occurs in individuals as much as 2 mm. in diameter. It is sometimes quite fresh, but is in places altered to cancrinite, hydronephelite, analcite and natrolite. These minerals also occur in little cavities and veins in the rock. Analyses of them by Dr. Harrington are given under V and VI, page 41. An analysis of the fresh nepheline separated from the nepheline syenite of the Corporation quarry was also made by Dr. Harrington and is given in the same table, No. II.

The *hornblende* often possesses fairly good crystalline form. It is brown in colour and strongly pleochroic. The single individuals sometimes vary in composition, as shown by the varying depth in colour, and they very frequently have a greenish border.

The *pyroxene* is in part a variety having a purplish colour and probably allied to that occurring in the essexite. But in addition to this variety of pyroxene, both aegerine and acmite occur in the rock and are sometimes present in the same slide. An analysis of the aegerine from one of the pegmatite veins of the nepheline syenite is given on p. 41, under No. IV.

The *mica* is pale brown in colour and is present in distinctly subordinate amount. Lepidomelane, found in the pegmatitic segregations of the nepheline syenite, has been analysed by Dr. Harrington.

Nosean which is not usually found as a constituent of nepheline syenite, is quite abundant in the rock, occurring as rather large, well defined idiomorphic crystals. It is usually turbid from the presence of minute inclusions and frequently shows a marked zonal structure.

	I Nepheline syenite, Corporation quarry Montreal. (M. F. Connor).	II Nepheline from nepheline syenite pegmatite. Montreal. (B. J. Harrington).	II Lepidomeane from nepheline syenite pegmatite. Montreal. (B. J. Harrington).	IV Aegerine from nepheline syenite Pegmatite. Montreal. (B. J. Harrington).	V Natrolite Corporation quarry, Montreal. (B. J. Harrington).	VI Analcite Corporation quarry, Montreal. (B. J. Harrington).
SiO_2	55·90	44·98	32·96	49·51	47·09	54·83
TiO_2	·70		2·80	·61		
Al_2O_3	19·75	32·65	10·34	2·72	26·99	24·20
Fe_2O_3	1·00	·72	8·85	22·26	tr. ce.	
FeO	2·05		27·19	5·82		
MnO	·10		2·79	1·51		
MgO	·59		·73	1·09		
CaO	3·10	trace...	·64	7·16	trace.	·08
SrO	trace...					
BaO	·09					
Na_2O	7·25	16·08	·98	8·62	16·46	12·01
K_2O	5·61	4·54	7·75	·38	·01	
P_2O_5	·01		Li_2O ·03			
Cl	trace.		F none.			
S	·64					
SO_3	·04					
CO_2	1·85					
H_2O (above 110° C.)	2·00	·97	4·36	·57	9·80	8·50
H_2O (at 110° C.)						
	100·77	99·94	99·42	100·25	100·35	99·62

The *sphene* is abundant in small but perfect wedge-shaped individuals. It sometimes shows a rather remarkable decomposition into calcite traversed by little needles of rutile.

The *garnet* is of dark reddish brown colour and occurs in individuals often of considerable size but of very irregular shape, and which hold numerous inclusions of nosean and orthoclase.

The Dyke Rocks.

The greater part of the district about Mount Royal is covered by drift of varying thickness. There is scarcely a place, however, in the area, where the drift is absent, that the underlying strata are not seen to be cut by dykes consanguineous in character with the rocks forming the intrusive mass of the mountain. Similar dykes, though in smaller number, cut the rocks of the mountain itself.

About 375 of these dykes and sheets have been observed on the Island of Montreal, and evidently a very much greater number are covered by the drift. The dykes range from a mere film to six feet (1·8 m.) or more in width. They are especially abundant on the slopes of Mount Royal about Westmount reservoir, in Outremont, in the area now covered by the waters of the Lower Reservoir (adjacent to the grounds of McGill University and formerly known as the Reservoir Extension), and along the harbour front. Dykes are also excellently exposed at the Mile End quarries, the Corporation quarry, Maisonneuve and elsewhere.

Unfortunately the rocks composing these dykes are, in almost all cases, considerably altered, and it is rare to find one which is entirely free from decomposition products. In many cases the alteration has progressed so far that it is impossible to determine the precise character of the original rock. As a rule, the dykes at Outremont are fresher than those of Westmount or from the Reservoir Extension.

The following types of dyke rocks are represented:—

Bostonite	Monchiquite
Aplite	Fourchite
Nepheline aplite	Camptonite
Tinguaite	Alnoite
Analcite dykes.	



Dykes cutting the Trenton limestone. Near Westmount Reservoir, Montreal.

An approximate determination of the relative abundance of these several rocks is afforded by an examination recently made by Professor Allan of specimens of 65 dykes occurring in various parts of Mount Royal and its vicinity and which may be taken as representative of the whole complex. His results show that the several types above mentioned were present in the following proportions:—

Bostonite	4
Tinguaite	14
Analcite dykes	3
Monchiquite	12
Fourchite	1
Camptonite	30
Alnoite	1
	65

Bostonite.—Dykes of this rock are not very common. One of the largest was exposed in former years at the Reservoir Extension (see p. 49), representing the earliest of the several sets of dykes at this locality. It is of a buff colour and has the structure and appearance of a typical bostonite, but is a good deal altered. Dawsonite a remarkable carbonate of alumina and soda which was originally discovered at this locality occurs on the selvage of this dyke in contact with the limestone. An analysis of the rock after treatment with nitric acid which removed 3·33 per cent. of calcite, and smaller amounts of alumina and ferric oxide, is given under I on page 46. As will be noted, it has a high content of soda as compared with the potash.

A bostonite sheet forms the greater part of Moffat's Island, opposite Montreal. Dykes of the rock are also found in the tunnel which is being driven through Mount Royal.

A small area of a reddish aplite cuts the camptonite breccia at Outremont. This is fresh and contains a little quartz. It is seen on the surface and is also traversed by the tunnel above mentioned. An analysis of the rock from the tunnel is given under II, page 46. It ranks as a phlegrose in the Quantitative Classification.

Tinguaite.—This rock occurs abundantly in dykes and sheets, more especially in the district northeast of

Mount Royal, between Côte de la Visitation and Maisonneuve. It is a fine-grained, greenish-grey rock and is often very fresh. It is quarried for road metal and concrete at several points in the district mentioned above. It very frequently contains nosean and under the microscope is also seen to hold small amounts of rinkite, lavenite and other rare minerals, owing to whose presence it is highly radio-active. An analysis of the rock from the quarry at Papineau avenue is given under III, page 46.

Nepheline Aplite.—Small dykes of this rock, usually quite narrow, are seen at the Corporation quarry and elsewhere in the district. The rock is light in colour, and often nearly white, and is composed of nepheline and orthoclase. It is frequently rather coarse in grain, thus approaching a nepheline syenite pegmatite in character.

Analcite dykes.—These dykes are bluish-grey in colour and have a peculiar pitchy lustre. They contain a large amount of an isotropic base, in which there are embedded a few phenocrysts which are almost exclusively of an alkali feldspar and nepheline. The isotropic base has the refractive index and composition of analcite. The isotropic base of monchiquites has been shown by Pirsson, in certain cases at least, to be analcite and not glass. It is believed that the base in these rocks is also analcite, although it has not been possible as yet to obtain any positive proof that such is the case. One of the largest and most typical of these dykes is to be seen at the Mile End quarries. An analysis of it is given under VI, p. 46. The rock is vey fresh and free from decomposition products. It ranks as laugenose in the Quantitative Classification.

Monchiquite.—These rocks resemble the camptonites in being very dark or black in colour and fine in grain, but differ from them in that they possess a groundmass or basis of some isotropic material. The two rocks cannot as a general rule, be distinguished in the field. Although not so abundant as the camptonites in this region, they are very common and form one of the most characteristic classes of dyke rocks connected with the intrusions of Mount Royal. They occur in all parts of the area, but are usually considerably altered. Analyses of two of these dykes are given (Nos. VII and VIII) on page 46. The first (No. VII) is a hornblende monchiquite from a dyke 18 inches (46 cm.) wide cutting the Trenton limestone at

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
	Bostonite.* Reservoir Ext., Montreal. (T. S. Hunt).	Aplite, West portal of tunnel, Mount Royal. (M. F. Connor).	Tinguaite, Papineau Ave., Montreal. (M. F. Connor).	Nepheline syenite, West portal of tunnel, Mount Royal. (M. F. Connor).	Aegerine Nepheline syenite, West wall of Westmount quarry, Montreal. (M. F. Connor).	Analcite dyke, Mile End quarry, Montreal. (M. F. Connor).	Monchiquite, Reservoir Ext., Montreal. (B. J. Harrington).	Monchiquite, Mile End quarry, Montreal. (M. F. Connor).	Camptonite, Reservoir Ext. Montreal. (B. J. Harrington).	Camptonite, Reservoir Ext. Montreal. (B. J. Harrington).	Camptonite, Mount Royal. (M. F. Connor).	Alnoite, Point St. Charles, near Montreal. (M. F. Connor).	Alnoite, Ste. Anne de Bellevue, near Montreal. (P. H. LeRossignol).
SiO_2	62·90	63·00	50·40	49·96	45·68	53·99	36·69	37·34	45·51	40·95	43·36	29·24	35·91
TiO_2		·48	·50	2·73	2·58	·25	5·44	3·93	3·84	3·39	3·00	2·40	·23
Al_2O_3	23·10	17·92	21·83	16·53	18·26	22·89	11·96	11·84	15·84	16·45	14·52	11·40	11·51
Fe_2O_3		·50	2·51	3·18	2·87	1·04	5·45	5·37	1·90	13·47**	1·45x	5·84	2·35
FeO		·90	1·41	4·35	3·98	·44	8·90	6·40	7·59		6·13	4·74	5·38
MnO		·03	·27	·10	·14	·23	·38	·18	·40	·33	·15	·15	
CaO	·45	1·50	3·17	8·24	8·06	·32	10·28	11·92	8·35	10·53	10·53	18·35	13·59
BaO		·02	·33	·05	·01		trace.	·04	·12		·01	·24	
Sx_2O		trace.	·07	·02	·02			·02			·01	·15	
MgO		·93	·39	3·95	2·63	·07	7·85	9·66	3·85	6·10	7·12	10·38	17·54
Na_2O	8·69	5·93	9·96	4·81	6·41	10·79	3·88	2·91	5·09	4·00	3·35	1·44	1·75
K_2O	2·43	6·08	6·10	2·95	3·81	4·87	2·07	2·05	1·88	1·28	1·88	2·42	2·87
P_2O_5		·05	·10	·32	·22		·62	·04	·61	·29	·24	2·10	not det.
CO_2		1·15	none.	·80	2·90	none.	3·78	5·08	2·23		·64	5·02	
Cl		·27	·10	·22	·10	·15	·04	·04	·05		.10	trace.	
SO_3		·03	·62			·06	·92		·60		·25	·33	
FeS_2		·50		·137	·38			·47			·47	S. ·17	
Fe_7S_8					·80			trace.			5·60		
H_2O (above 110° C.)	1·40	·50	2·35	·70	·75	4·70	1·70	2·56	1·67	3·84***	1·28	5·05	9·40xx
H_2O at 110° C.)		·06	·15	·07	·07	·18	·25	·24	·16		·32	1·04	
	98·97	99·85	100·26	100·35	99·67	99·98	100·21	100·09	99·69	100·63	99·84	100·45	100·51

*After treatment with dilute nitric acid. **All the iron is calculated as Fe_2O_3. ***This is "loss on ignition" and is largely CO_2.

xOn account of the evolution of H_2S during analysis, the relative quantities of Fe_2O_3 and FeO as given are as accurate as can be determined. There is, however, probably less FeO and more Fe_2O_3 than the figures indicate.

xxWith CO_2.

the Reservoir Extension. It is composed of phenocrysts of deep brown hornblende, with iron ore and a small amount of accessory pyroxene and olivine, in an isotropic groundmass which also holds some small laths of plagioclase and a little nepheline. The second (No. VIII) is from a dyke which occurs at the Mile End quarries, but which is now concealed by a recently constructed road.

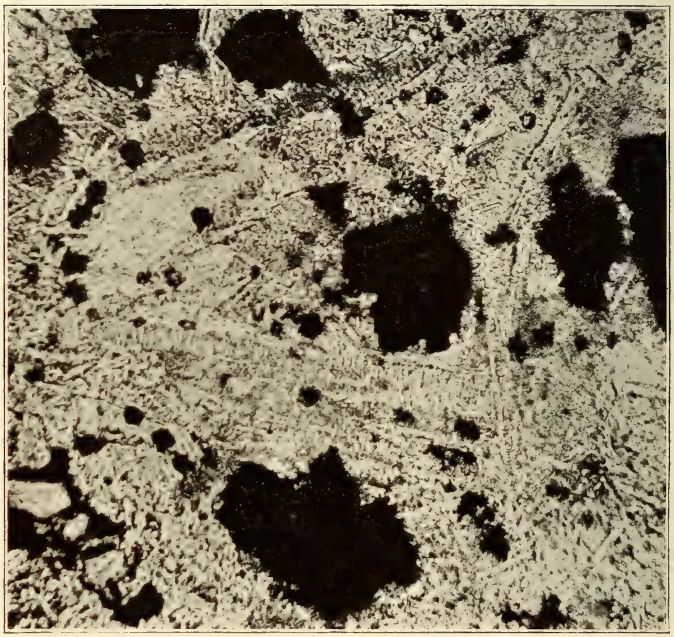
Fourchite. This is an olivine-free augite hornblende monchiquite which is represented by a few dykes. See St. Helen's Island, p. 59.

Camptonite. The camptonites are dark in colour, fine in grain, holocrystalline and often porphyritic. They frequently show a more or less banded structure parallel to the walls, and, like the monchiquites, are occasionally amygdaloidal, the cavities being filled with zeolites or rhombohedral carbonates. They usually belong to the subdivision of the hornblende camptonites, the rock being composed of hornblende (deep brown), pyroxene and plagioclase as essential constituents with accessory nepheline, perowskite, apatite, iron ore, &c.

Analyses of three of these dykes are given on page 46. The first two (Nos. IX and X) occur at the Reservoir Extension and were analysed by Dr. B. J. Harrington. The third (No. XI) is an exceptionally fresh camptonite from Mount Royal recently analysed by M. F. Connor.

Alnoite. These olivine-rich biotite monchiquites, holding melilite and perovskite, are excellently represented in this area. It is one of the few places in the world where these rocks are found. Unfortunately it is impossible for the members of this excursion to see the rock in place, since the localities where it occurs are difficult of access, or the dykes at one time laid bare are now covered by the waters of the St. Lawrence or Ottawa rivers. The first locality in which alnoite was found was in a dyke cutting the Potsdam sandstone in the bed of the Ottawa river at Ste. Anne-de-Bellevue at the west end of the Island of Montreal, where it was laid bare many years ago in a cofferdam put down for the purpose of blasting away an obstruction in the river bed. It occurs as a dyke rather over two feet (·6 m.) wide, the rock presenting a very striking appearance owing to the presence of large rounded

individuals of red olivine with large plates of brown mica. The melilite and perovskite lie in the finer grained groundmass. An analysis of this rock is given on page 46, under No. XIII.



Microphotograph of alnoite. Point St. Charles, Montreal. The lath-shaped crystals are melilite showing peg structure.

Another dyke of alnoite was laid bare on the river bottom near the approach to the Jubilee bridge at Point St. Charles when the water was very low in 1895.

This is rather more than two feet wide and cuts a smaller fourchite dyke. It contains about 20 per cent. of melilite. A microphotograph of a thin section of this rock showing the melilite is on this page. An analysis of the rock is given under No. XII, page 46.

Alnoite also occurs forming the paste of the igneous breccia on Ile Bizard, as well as in dykes cutting this breccia. In the latter the melilite often forms 25 per cent. of the rock

and frequently occurs as wreaths or coronas about the previously crystallized olivines and augites.

Rocks allied to alnoites also occur at La Trappe and St. Lin.

Annotated Guide.

Starting from the main gate of McGill University the party will walk through the southern campus which is situated on one of the marine terraces cut into the slopes of Mount Royal at the time of the post-glacial submergence. This terrace is 152 feet (46·3 m) above sea level. It consists of the Saxicava Sand underlain by the Leda Clay. The latter holds many shells of marine invertebrates which still live in the cold waters on the coast of Labrador. Among these may be mentioned—*Saxicava rugosa*, *Leda minuta*, *Leda arctica*, *Mytilus edulis*, *Macoma grœnlandica*, *Balanus crenulatus*, *Mya truncata*, *Lepralia quadricornuta* and others. These stratified post-glacial deposits rest on glacial till which in its turn rests on a glaciated surface of the underlying Trenton limestone. This deposit of till and stratified drift is 50 feet (15 m.) thick at the gate of the campus, but the surface of the underlying limestone gradually rises toward the mountain and the drift at the northern end of the playing field is only 18 feet (5·5 m.) thick.

Leaving the University grounds by the western gate and passing up McTavish street, the basset edges of the Trenton limestone will be seen on the cliff behind the Low Level Reservoir. This body of limestone, when the reservoir was being excavated some 37 years ago, presented a striking appearance, being intersected by a swarm of dykes. No less than 30 of these were mapped by Dr. B. J. Harrington in an area measuring 200 yards (182 m.) in length by 100 yards (91 m.) in breath and were found by him to belong to at least seven periods of intrusion. They embraced bostonites, tinguaites, camptonites, monchiquites and probably other allied types, which, however, were all found to be considerably altered, so much so in some cases that it was impossible to ascertain with certainty their original character. Analyses of three of these dykes are given on page 46). It was upon the wall of a large bostonite dyke cutting the limestone here, that the mineral dawsonite was discovered. This rare carbonate of alumina

and soda occurred as a beautiful network of colourless transparent bladed crystals on the side of the bostonite dyke along its contact with the limestone.

These dykes, which were so well exposed when the reservoir was in course of excavation, are now concealed beneath its waters, except where some of them intersect the cliff behind the reservoir, but even here they are now but indifferently seen, being concealed by the vegetation and by the wash from above.

On Pine avenue the Trenton limestone is well exposed and is cut by a few small dykes. Above this, the road, winding up the mountain side, passes over almost continuous exposures of the same limestone in heavy beds dipping at a very low angle to the south until the level of the upper reservoir is reached.

Here the Trenton is overlain by a hornstone, representing a remnant of the Utica shale which lies immediately against the essexite, by which it has been intensely altered.

Climbing a steep declivity over this highly altered Utica shale, the essexite which forms the greater part of Mount Royal is reached. This is well exposed near "the Lookout".

From this *Lookout*, if the day is clear, a magnificent view may be had over a portion of the St. Lawrence lowland, with the River St. Lawrence flowing through it, and the city of Montreal situated by the side of the river, at the head of navigation for ocean-going vessels. It was probably from about this point that Jacques Cartier, the first white man to ascend the St. Lawrence, stood when in 1535 he looked over the same landscape, and, here later explorers believing that it must be the land of Cathay for which they were in search, exclaimed: "C'est La Chine," a name (Lachine) which has ever since that time been borne by the rapids which impede navigation just above the city of Montreal, as well as by the little town which has grown up beside them.

Standing here on Mount Royal, all the other Monteregian Hills are in full view and form striking features in the landscape. These are, in their order, Montarville (St. Bruno), Beloeil, Rougemont, Yamaska, Shefford and Brome, while further south the intrusive plug of Mount Johnson is seen, isolated and rising abruptly from the plain.

Beyond the Monteregian Hills in the far east some of the higher points of the Notre Dame mountains, which in Canada represent the Appalachian Mountain folding, are visible, while to the southeast on the horizon are the Adirondack mountains in the State of New York. These latter are of Laurentian age, forming a great outlying island of the Canadian Shield, completely surrounded by sediments of Paleozoic age. About 100 yards west of the Outlook are the exposures of essexite described on p. 37.

Proceeding northward from the Lookout another exposure of essexite traversed by many dykes is seen in a fine cliff by the roadside, in which, however the rock is considerably decomposed. This decomposition is seen in a still more striking manner in exposures occurring at the back of the Protestant cemetery, where the rock has crumbled into a deep brown residual soil. Near this point the highest post-glacial beach deposit (568 feet above sea level) on Mount Royal is found.

Continuing across the mountain, through the Roman Catholic cemetery, the fresh essexite, often very basic in character, is again exposed. In this cemetery the first evidence of the existence of a second great intrusive mass in Mount Royal—the nepheline syenite—is seen.

This rock occurs here in the form of dykes, light in colour, which cut the dark essexite and often enclose angular fragments of it.

Passing down the steep northerly slope of Mount Royal, a fine view across the plain to the north is obtained, with the highlands of the Laurentian Protaxis (Canadian Shield) bounding the horizon. At the foot of this slope is the Corporation (Forsyth's) Quarry.

This quarry was worked for many years, the nepheline syenite obtained from it being used as road metal in the city of Montreal. This rock is seen to be intruded between the essexite of the mountain and the Trenton limestone which here underlies the plain. It cuts through both rocks, sending apophyses into the essexite of which it also holds many inclusions and metamorphosing the blue fossiliferous Palæozoic limestone into a very coarse grained white marble.

A great swarm of dykes, representing the latest phase of the igneous activity, in their turn traverse the whole complex.



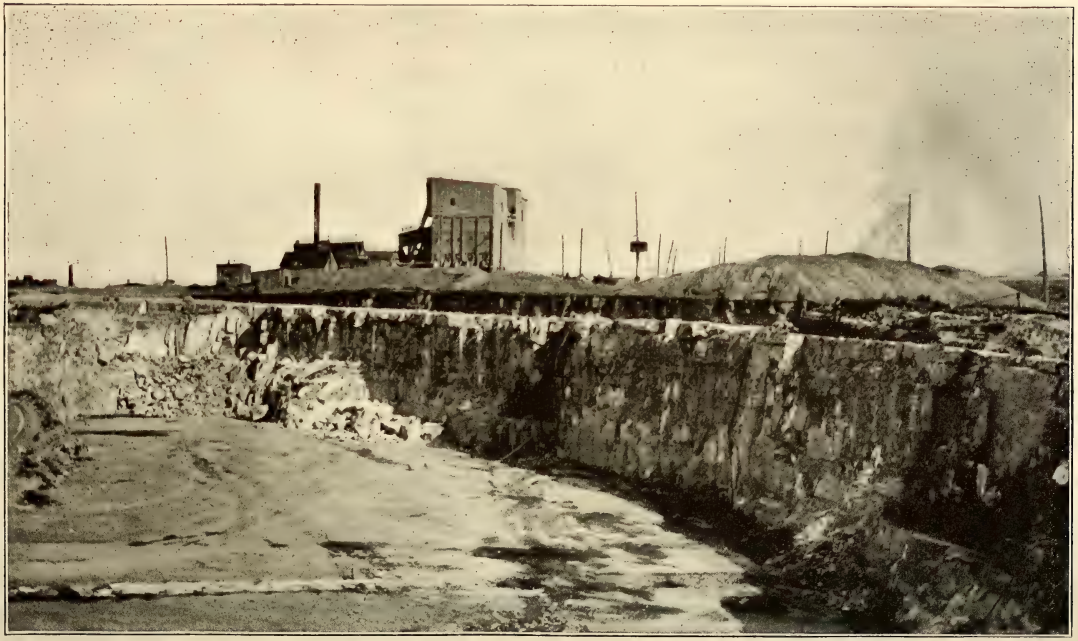
Contact of nepheline syenite (on left) with Trenton limestone (on right). The limestone is highly altered. Both rocks are cut by numerous dykes. Corporation quarry, Outremont, Montreal.

The alteration of limestone by the intrusion of the nepheline syenite is well seen at this quarry. The zone of alteration is not wide, but the alteration along the immediate contact is intense, the limestone in places being changed to a coarse grained white marble. Certain exomorphic contact minerals have also been developed in parts of the altered limestone. In 1892 a vein of nearly pure native arsenic was found cutting the nepheline syenite near the contact, and about 40 lbs. of this mineral was obtained from the vein. The same mineral has been found, although in smaller amount, in driving the Canadian Northern tunnel, which passes through the contact below the surface at no great distance from this quarry.

Many of the dykes and small stock-like intrusions about Mount Royal contain angular fragments of the sedimentary strata through which the magma passed in its upward course. In certain places, these fragments are so abundant within the igneous rocks that the latter become igneous breccias.

An area within which these breccias are developed extensively is situated in Outremont, to the South of St. Catherine road and extending from Rockland avenue through the Golf Links to Mount Royal Heights. Here the prevalent type of breccia possesses a camptonite base and includes a great number of fragments of Trenton limestone, and, in places, a few of Potsdam sandstone. The limestone fragments have been, more or less changed, from their normal blue colour to white, and in some cases have been recrystallized, though in many of them the Trenton fossils can still be distinguished.

Upon Mount Royal Heights, many of the fragments of the Trenton limestone within the camptonite are very large, in places the stratification of this formation has been little disturbed, but it is traversed by irregular tongues of camptonite extending in every direction. Intrusive into the breccia is a small body of nepheline syenite, containing a large number of fragments of Potsdam sandstone. A few dykes of aplite (see analysis II, page 46) which are presumably genetically related to the nepheline syenite also break through the camptonite breccia at this point. At a depth of 160 feet below the surface the tunnel of the Canadian Northern Railway penetrates both of these igneous rock types. At this depth, the fragments of limestone within the camptonite are not so abundant as at the



Tinguaite sheet, with Trenton limestone above forming the floor of the quarry. Quarry at the head of Delorimier avenue, Montreal.

surface, while locally a few inclusions of Potsdam sandstone are present. The nepheline syenite ,which appears in isolated outcrops at the surface, widens below to several hundred feet. It contains many small rounded fragments of Potsdam sandstone which display every stage of absorption by the magma. The occurrence appears to have the form of a small stock which probably did not extend upwards much farther than the present surface of Mount Royal Heights.

In one of the quarries on the eastern outskirts of the city of Montreal, one of the large sheets of tinguaite which penetrate the limestone in this district is exposed. In the quarries of Morrison & Co., at Delorimier avenue this sheet attains a thickness of 25 feet. The Trenton limestone forms both the floor and the roof of the sheet, which is cut by younger dykes of fourchite, etc. In the quarries of Messrs. Rogers & Quick the pipe through which the magma rose to supply material for the sheet is seen, as well as the sheet itself. The tinguaite of this sheet is very fresh and typical. It is rich in nosean and holds also as accessory constituents rinkite, lavenite, rosenbuschite, and other rare minerals.

THE GEOLOGY OF ST. HELEN ISLAND.

The western end of this island is underlain by a soft, easily disintegrating shale of Utica age. This formation overlies the Trenton limestone. The contact of the two formations, which follows approximately the north bank of the river, is concealed by drift.

The remainder of the island is composed of a very remarkable breccia. This shows no signs of stratification and is composed of fragments of rocks of various kinds, which are angular, subangular, or partly rounded but not waterworn, embedded in a very fine grained greyish matrix which weathers to a rusty brown colour. These fragments vary in size from microscopic grains to boulders twelve and fifteen inches in diameter, and their range in age extends from Laurentian to Devonian. The rocks represented are red and black shales; hornstone; limestone —mainly Trenton; red and grey sandstones—the latter probably Potsdam; quartzite; granitic and syenitic gneiss. The red shale and red sandstone were considered by Logan to be probably of Medina age.

At one point only is the breccia to be seen in contact with the Utica. The contact is a brecciated one, the shale being broken up into angular fragments and the interstitial spaces being filled with a yellowish crystalline dolomitic material. Part of this shale has been altered to hornstone. The contact is not sharp, but there is a regular transition from the normal shale through the brecciated facies to the breccia proper.

It will be noted that there has been a distinct bleaching and alteration of the limestone fragments in the breccia about their borders, showing that the paste of the breccia has heated and metamorphosed the included fragments.

In addition to the ordinary inclusions, the breccia holds large masses of limestone which merit special mention. These occur on the north-east side of the island. Of these, the middle exposure is lenticular in shape, and is cut by a dyke which has been subsequently faulted. It has an area of about 100 square feet. The rock is a fine grained, light grey, friable limestone. The north exposure is 200 feet in length, and is a dark grey, fine grained semi-crystalline limestone which is somewhat bituminous. It has been brecciated along the contact with the breccia, and the angular fragments have been cemented by a paste which differs in composition from the limestone. On a weathered surface this matrix stands in relief, forming a complicated network, which shows the most minute detail in structure. Immediately south of these two, there is another large block of granular siliceous limestone also embedded in the breccia. These masses of limestone are all highly fossiliferous and have been made the subject of a careful palæontological study by Dr. H. S. Williams. He finds the first two masses to be of the same age, the Helderbergian of the New York series. The block of siliceous limestone is later and equivalent to the Oriskanian.

An exhaustive study of the fossils discovered in the several masses has furnished the following list of species, which Prof. Williams has severally designated as the *Spirifer arenosus* fauna and the *Gypidula pseudogaleata* fauna from the diagnostic species distinguishing them.

LIST OF SPECIES.

The Spirifer Arenosus Fauna.

(List of species from the northern exposure of limestone in the northeast part of the area of the limestone breccia, St. Helen's island.)

Chaetetes spæricus, Hall.
Small crinoid stems.
Orthis (Rhipidomella), cf. oblata, Hall.
Orthis (Dalmanella) subcarinata, Hall.
Orthis (Dalmanella), cf. quadrans Hall.
Leptæna rhomboidalis, Wilckens.
Orthothetes, cf. Woolworthana, Hall.
Chonetes hudsonicus metytype Gaspensis, Clarke.
Chonetes striatissimus, W. & B. ("cf. canadensis, small var," Bill).
? Camarotœchia sp. indet.
Uncinulus, cf. mutabilis, Hall.
Rhynchonella eminens, Hall.
Eatonia peculiaris, Hall (narrow var.).
Eatonia, cf. Whitfieldi, Hall.
Spirifer arenosus, Conrad.
Spirifer Montrealensis sp. nov. H.S.W.
Spirifer gaspensis, Billings.
Spirifer cumberlandiæ, Hall.
Spirifer cyclopterus, Billings (not Hall? = S. tribulis, Hall).
Cyrtina rostrata, Hall.
Metaplasia pyxidata, Hall.
Modiomorpha Helena sp. nov. (cf. concentrica.)
Palæoneilo ("cf. maxima, Clarke") Helena sp. nov.
Tentaculites Schlotheimi, Koken, cf. T. elongatus, Hall.
Spirifer pennatus, var. Helenæ, H. S.W. (See McGill College Collection, specimen No. 3644.)

The Gypidula Pseudogaleata Fauna.

(List of species from the southern exposure of limestone, the part to the west of the dyke in the breccia.)

Lichenalia, cf. torta, Hall.
Fenestella, sp. incert.
Crinoid stems.
Dalmanella, cf. subcarinata, Hall.
Dalmanella concinna, Hall.
Schizophoria multistriata, Hall.
Rhipidomella oblata, Hall.
Orthostrophia strophomenoides, Hall.
Leptæna rhomboidalis, Wilckens.
Stropheodonta arata, Hall.
Stropheodonta planulata, Hall.
= S. blainvillei, Billings.
= S. perplana, Hall.
Stropheodonta Beckii, Hall.
Stophonella punctulifera, Conrad.
Strophonella cavumbona, Hall.
Strophonella (Amphistrophia), continens, Clarke.
Strophonella Leavenworthana, Hall.
Orthothetes, cf. deformis, Hall.
Gypidula pseudogaleata, Hall.
Uncinulus planoconvexa, Hall.
Camarotœchia ventricosa, Hall.
Rhynchotrema formosum, Hall.
Spirifer concinnus, Hall.
Spirifer concinnus, var. Helenæ, v. nov.
Cyrtina Dalmani, Hall.
Atrypa reticularis (Linnæus).
Meristella princeps, Hall.
Merista lævis (Vanuxem).
Rensselæria, cf. mutabilis, Hall.
Platyceras, cf. clavatum, Hall.

(From the mass on the east side of the dyke in the southern exposure, belonging to the same fauna as above.)

Favosites helderbergiæ, Hall.
Cf. Lichenalia distans, Hall.
Orthis (Schizophoria) multistriata, Hall.
Stropheodonta arata, Hall.
Strophonella punctulifera, Conrad.
Orthothetes, cf. Woolworthanus, Hall.
Leptæna rhomboidalis, Wilckens.
Camarotœchia, cf. ventricosa, Hall.
Rhynchonella, cf. formosa, Hall.
Atrypa reticularis, Linn.
Spirifer, cf. concinnus, Hall.

Dr. Williams states that it seems quite evident from the critical study of the species that neither of these St. Helen's Island faunas is to be correlated exactly with any one of the known faunas of New York or of the interior of the American continent. Nor do they agree exactly with any of the more eastern faunas of Maine, Quebec, New Brunswick or Nova Scotia. Nevertheless, a resemblance is found for the first fauna with the Oriskanian and for the second fauna with the Helderbergian which they bear to no other faunas.

The matrix of the breccia under the microscope is seen to be composed largely of carbonates, as may also be ascertained by treating a hand specimen with dilute acid, but it also contains epidote, pyrite, apatite, perovskite, zircon, and, occasionally a mineral resembling hydronephelite. The original material is now completely decomposed. It was supposed by Sir William Dawson that this occurrence together with the other patches of breccia which occur on Ile Bizard and elsewhere, represented remnants of the ejectamenta from the ancient volcano of Mount Royal. This also was the view taken by Nolan and Dickson in their study of the occurrence. More recent investigations, of these other breccias, however, show that they have a matrix composed of camptonite, alnoite or other allied magmas and that the bodies have the character of intrusive masses. It seems probable, therefore, that the breccia of St. Helen's island also represents an intrusion of similar magma which has subsequently been so completely altered that its original character can be no longer recognized. This explanation also accounts for the distinct peripheral alteration so often seen in the fragments, more especially the limestone fragments, in the breccia.

The presence in the breccia of fragments of Upper Silurian and Devonian age has naturally been a source

of much speculation, for no rocks of so recent an age are found in place anywhere in the western portion of the Province of Quebec. Since,however, it has been shown that in all probablity the matrix of the breccia was in a molten condition when it enclosed the fragments, and that the breccia as a whole has acted as an intrusive, the explanation is rendered comparatively simple. The breccia apparently represents the truncated pipe or outlet of a reservoir of molten igneous material, which outlet may have reached the surface and even formed a subsidiary cone on Mount Royal, or else it may have been of the nature of a laccolitic mass, not opening on the surface. In either case the intrusion extended up into the Helderberg and Oriskany which must have overlain the Utica in this district. The intrusive mass stoped off blocks from these higher strata which either sank of their own accord to the level of Utica, or in the surgings of the magma, such as are to be seen in volcanoes to-day, were, at a time when the lava was sinking, carried to the lower level.

The presence of these inclusions in the breccia proves that the intrusion must have taken place subsequent to the deposition of the formations represented by the included fragments. The breccia is therefore of post-Oriskany age.

Similar occurrences in which intrusive masses hold inclusions of fossiliferous sedimentary rocks more recent than any now exposed in the surrounding region have been described by Kynaston and Hall,* as well as by Peach and Gunn and others.**

The Utica shale and the breccia of St. Helen's island are cut by a number of dykes and small sills representing several varieties of the consanguineous dyke rocks of the Mount Royal intrusions. Among these is the faulted dyke referred to above as cutting the mass of Lower Helderberg limestone included in the breccia. This rock is basaltic in appearance and possesses both a porphyritic and an amygdaloidal structure. The amygdules are filled with calcite and analcite, the former mineral usually occupying the centre of the cavity. The rock is composed of phenocrysts of pyroxene and hornblende, embedded in a groundmass consisting of the same ferro-magnesian constituents with much analcite. The rock is a fourchite.

*Diamondiferous Deposits—Geological Survey of the Transvaal. Report for the year 1903, p. 44.

**On a Remarkable Vent of Tertiary Age on the Island of Arran, enclosing Mesozoic Fossiliferous Rock. Q. J. G. S. 1901, p. 226.

MOUNT JOHNSON.

Annotated Guide.

Miles and Kilometres.

Altitude 58·5 ft. (17·8 m.)—Leaving Bonaventure Station by the Grand Trunk Railway the train crosses the St. Lawrence river on the Jubilee bridge. This bridge was built to replace the old Victoria bridge designed by Stevenson. It is 9,184 feet in length, being one of the longest bridges in the world.

0 m. 0 km. **Montreal.**

3 m. 4·8 km. **Point St. Charles.**

From the bridge a very fine view of the city of Montreal is obtained.

The railroad passes over the great plain of the St. Lawrence lowlands underlain here by nearly horizontal strata of Ordovician age. The plain is mantled by drift of no great thickness. In its present form it represents the sea bottom of the glacial estuary of the St. Lawrence laid bare by the retreat of the ocean at the close of the Glacial age.

6·16 m. 9·9 km. **St. Lambert.**

7·98 m 12·8 km. **Ranelagh.**

11·96 m. 19 km. **Brosseau Junction.**

20·18 m. 32·5 km. **Lacadie.**

The train here crosses the Richelieu river, a tributary stream which enters the St. Lawrence at Sorel. It is an industrial centre with large pottery works, silk factory, etc., and a military post with Infantry school.

27 m. 43·4 km. **St. Johns.**

The Richelieu in early times was called Rivière des Iroquois because the war parties of the Mohawk Indians came up by it from the south when making their raids upon the settlements in the St. Lawrence valley. The English and French armies traversed it incessantly during

28 m. 45 km. **Iberville Junction.**

32 m. 51·5 km. **Mount Johnson.**

the Colonial wars, and the names of the places along its banks, such as Sorel, Ours, Chambly are those of officers of one the French regiments, who received the first land grants when these regiments were disbanded.

Geology of Mount Johnson.

Mount Johnson rises from the plain 22 miles (35 km.) east-southeast of the city of Montreal as the crow flies, and 25 miles (40 km.) north of the international boundary. The little village of St. Grégoire is situated near its base. The surrounding country is perfectly flat, forming a fertile and well tilled agricultural district, the nearest mountain being Rougemont, another of the Monteregian Hills, which lies some nine miles distant in a northeasterly direction. In cross-section Mount Johnson is approximately circular. The igneous plug itself has at the base, immediately above the hornstone collar, a somewhat elliptical outline, and measures 3,500 feet (1066 m.) by 2500 feet (761 m.), the longer axis having a direction N. 20° E. This gives the igneous intrusion an area of ·423 of a square mile. The mean of a series of closely concordant aneroid readings, corrected by comparison with barometers at the observatory at McGill University at Montreal, shows that the highest point of the mountain is 685 feet (208·8 m.) above the main street in the village of St. Grégoire opposite the church, that is, above the surrounding plain, or 875 feet (266·7 m.) above sea level, the plain here having an elevation above sea level of 190 feet (58 m.) It has a somewhat dome-like outline, and forms a very striking feature in the landscape. The slope on the southern side is steep, in places precipitous, while to the north it is more gentle. The accompanying photograph taken from the railway station near St. Grégoire, which is about a mile and a quarter distant from the mountain in a direction approximately southwest, shows this profile, as well as the little notch near the summit, caused by a ravine which passes down the side.

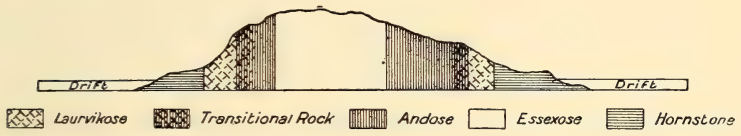
At the foot of the mountain, more especially on its southern, southeastern and southwestern sides, are numbers of large blocks which have fallen from the steep upper



Mount Johnson as seen from the southwest, showing the limits of the several rock types composing the mountain.

slopes; on the southern side is a gentle sloping terraced platform of drift which in part buries these great blocks, forming a "tail" probably due to the drift accumulating here on the lee side of the mountain during the ice movements in the Glacial age. This drift, however, has been in part at least reassorted by wave-action during the period of depression which in this region followed the Glacial age and during which the sea covered the plain to a depth of several hundred feet at least. On the plain about the mountain no rock exposures are seen. A mantle of drift covers it, and numerous erratic blocks and boulders are scattered about. These are composed chiefly of gneiss from the Laurentian highlands, but some of them are plutonic rocks from other hills of the Monteregian group.

On ascending the mountain the first rock which is exposed above the drift mantle is a very fine-grained dark hornstone, uniform in character and lying in undisturbed horizontal beds. It can be seen at intervals all around the base of the mountain, forming a sort of collar, and is undoubtedly a shale such as that usually constituting the Utica formation, here however altered by its proximity



Diagrammatic section through Mount Johnson, showing the relation of the several rock types.

to the intrusion. This shale, wherever seen, lies flat and abuts against the igneous rock of the intrusion, being cut off sharply by it, but is not tilted or upturned. The upper limit of the shale is shown in the accompanying photograph of the mountain.

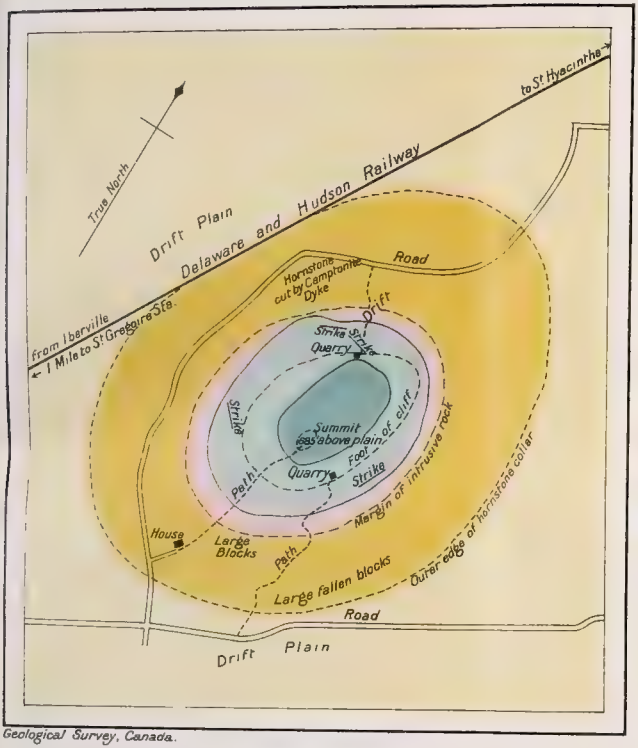
The mountain above this hornstone collar is made up exclusively of igneous material, which presents a most striking and beautiful instance of differentiation.

Immediately above the hornstone collar, and in contact with it, is a coarse-grained and highly feldspathic syenite, light buff in colour, of the pulaskite type. This, as the mountain is scaled, passes rather abruptly into a dark-coloured rock with large porphyritic white feldspars,

which in its turn loses its porphyritic character and passes into a coarse-grained essexite which constitutes the mass of the hill, and which becomes at the summit finer in grain, richer in pyroxene and often holds a little olivine. No sharp lines can be drawn between these several rocks; one passes gradually into the other, the whole constituting one intrusive unit. The approximate limits of these several rock species are shown in the accompanying map and photograph of the mountain, it being impossible sharply to delimit the several species. The mass therefore becomes progressively more basic from the margin of the intrusion to its centre. The two chief rock types are the pulaskite and the essexite which will be separately considered.

The Pulaskite.—This soda-syenite which, as above mentioned, forms the outer zone of the intrusion, girdling the essexite, is less abundant than the latter, and differs greatly from it in appearance. This difference is due chiefly to the fact that it is pale yellow or buff in colour, instead of dark grey, the lighter colour being due to the very small proportion of iron-magnesia constituents present and the marked preponderance of the feldspars. The rock also has a more massive structure without the fluidal arrangement of constituents often met with in the essexite, and it weathers in a somewhat different manner. It possesses, moreover, a species of porphyritic structure, owing to the development of the feldspar in two forms; first, as stout prisms, up to 10 mm in diameter, which are light grey in colour and very abundant; and, secondly, in the form of smaller laths of a yellow or buff colour which, in association with the iron-magnesia and other constituents, form a sort of ground mass in the rock.

The constituent minerals of the rock are biotite, hornblende, soda orthoclase, nepheline, sodalite, apatite, magnetite and sphene. The darker contituents are identical in character with those occurring in the essexite. Not only are they as a class much less abundant in this pulaskite, but the mica here preponderates, while the hornblende is much less abundant and the pyroxene is entirely absent. It may be noted, however, that the hornblende sometimes possesses the greenish tint referred to as occasionally seen about the borders of the hornblende individuals in the essexite, indicating probably that the pulaskite magma being richer in soda,



Geological Survey, Canada.

Mount Johnson

Feet
1000 0 1000 2000 3000

Metres
100 0 500 1000

Legend

- Drift
- Pulaskite (Laurvikose)
- Essexite (Andose)
- Essexite (Essexose)
- Hornstone (altered Lorraine shale)



the hornblende crystallizing out of it had a tendency to take up this element.

The *feldspar* in the pulaskite, as has been mentioned, occurs in part as stout prisms and in part as smaller laths. The latter usually have a somewhat cloudy appearance under the microscope, probably owing to the incipient alteration. The larger feldspars are what is commonly described as soda-orthoclase. When examined under the microscope they are seen to be composed of very minute intergrowths of two, and in some cases perhaps even of three, different feldspars—causing them to present between crossed nicols a mottled appearance. These several feldspars have somewhat different indices of refraction, and frequently under a high power, where two are present, one of them can be seen to possess a very minute polysynthetic twinning, while the other is untwinned. The relative proportion of the several feldspars present differs in different grains. The individuals as a whole occasionally present the form of carlsbad twins, but usually have the appearance of simple crystals and consist of microcline, microcline-microperthite, with probably some anorthoclase

The smaller lath-shaped feldspars, although more frequently composed of a single species, often show an intergrowth of two feldspars, as described in the case of the phenocrysts. Separations of the constituents of several species of the rock by means of Thoulet's solution show that the smaller feldspars have a somewhat lower specific gravity than the phenocrysts, that is to say, the smaller feldspars approach more nearly to pure orthoclase in composition. No lime-soda feldspar can be recognized in any specimen of the rock.

Nepheline and sodalite are quite subordinate in amount, although they are seen in nearly every thin section. Both minerals present the same characters and occur in the same way as in the essexite, lying chiefly in the corners between the other constituents, being penetrated by the latter, but also occurring as inclusions in the feldspar. They are, as a general rule, much altered to the same decomposition product in the nepheline of the essexite and which is either kaolin or muscovite. Probably both are present.

Apatite is present in considerable amount and in the form of perfect crystals, occuring chiefly in the mica, hornblende and sphene. The *iron ore* and *sphene* present

the same characters as in the case of the essexite, but the latter mineral is relatively more abundant than in that rock.

An analysis of this pulaskite is given in the accompanying table together with analyses of the pulaskite and the nordmarkite of Shefford mountain described by Dresser. Analyses of three allied rocks from other localities are added for purposes of comparison.

—	I.	II.	III.	IV.	V.	VI.
SiO_2	57·44	59·96	65·43	56·45	59·01	60·03
TiO_2	1·97	0·66	0·16	0·29	0·81	
Al_2O_3	19·43	19·12	16·96	20·08	18·18	20·76
Fe_2O_3	1·69	1·85	1·55	1·31	1·63	4·01
FeO	2·70	1·73	1·53	4·39	3·65	0·75
MnO	0·25	0·49	0·40	0·09	0·03	trace.
MgO	1·16	0·65	0·22	0·63	1·05	0·80
CaO	2·66	2·24	1·36	2·14	2·40	2·62
BaO	not det.	·12	none.		·08	
Na_2O	6·48	6·98	5·95	5·61	7·03	5·96
K_2O	4·28	4·91	5·36	7·13	5·34	5·48
P_2O_5	0·60	0·14	0·02	0·13	trace.	0·07
SO_3	not det.	0·08	0·06			
Cl	trace.	0·14	0·04	0·43	0·12	
H_2O	1·03	1·10	0·82	1·51	0·50	0·59
	99·69	100·17	99·86	100·19	99·98	101·07

I.—Pulaskite (laurvikose), Mount Johnson, Quebec.
II.—Pulaskite (laurvikose), Shefford mountain, Quebec.
III.—Nordmarkite (nordmarkose), Shefford mountain, Quebec
IV.—Sodalite syenite, Square Butte, Montana (differentiation product of shonkinite.)
V.—Umptekite, Red Hill, Moltonboro, New Hampshire.
VI.—Pulaskite, Fourche mountain, Arkansas (original locality).

The mineralogical composition (mode) of the Mount Johnson pulaskite (No. I), calculated from the analyses given above, is as follows:—

Albite	48·73	
Anorthite	3·06	74·03
Orthoclase and microcline	22·24	
Nepheline		2·56
Kaolin		4·96
Hornblende		5·08
Biotite		6·29
Magnetite	1·87	2·77
Ilmenite	0·91	
Sphene		2·35
Apatite		1·34
Water (hygroscopic)		0·30
		99·68

The calculation shows clearly the fact, ascertained by the study of the thin sections of the rock, that a considerable percentage of sphene is present, a mineral which does not occur at all in the essexite.

The calculation also brings out clearly the fact that in this rock the nepheline is much more highly altered than in the essexite, as shown by the amount of kaolin present. This kaolin, however, is not entirely derived from the alteration of the nepheline, but appears as a haze through all the smaller feldspars, and hence in the extension of the results should be assigned in part to the nepheline and in part to the feldspar.

In the Quantitative Classification the rock would have the following positions:—

Class I, Persalane.
Order 5, Canadare.
Rang 2, Pulaskase.
Subrang 4, Laurvikose.

It is thus seen that the rocks from Mount Johnson and from Shefford mountain which, following Rosenbusch's classification, have been called pulaskite, and which in the quantitative scheme of classification are pulaskase, are almost identical in composition with one another and with the Norwegian laurvikite, and that the nordmarkite of Shefford mountain is very close in composition to the nordmarkose of the original Scandinavian locality.

The Transition Rock. As has been mentioned, there intervenes in Mount Johnson between the pulaskite

border and the central mass of essexite a transitional zone consisting of a rock which is dark in colour and thus resembles the essexite, but which is characterized by the presence of large porphyritic feldspars, sometimes as much as two inches in length, of peculiar form scattered through it and often arranged with their longer axes in the same direction, thus giving a fluidal appearance to the rock. This rock contains a large proportion of the same iron-magnesia minerals, more especially the hornblende, found in the essexite, and passes over gradually into this rock. Its passage into the pulaskite is rather more abrupt and is marked chiefly by the almost entire disappearance of the dark-coloured constituents above mentioned. There is, however, a continuous transition from the pulaskite through this intermediate rock into the inner essexite of the mountain.

This transitional rock is composed of the same minerals as the essexite with the exception of the feldspar, which consists in part of the soda-orthoclase characteristic of the pulaskite, and in part of the plagioclase (in this case oligoclase) which forms the feldspathic element of the essexite. It is thus in mineralogical composition intermediate between these two rocks, although, as above mentioned, being rich in the dark coloured constituents, it more closely resembles the latter.

The large feldspars have frequently a peculiar crystalline form giving to the mineral, when broken across, a perfect hexagonal outline. The six faces represented in this form are apparently T, L, and M. The crystals hold many little inclusions of pyroxene, biotite, hornblende, magnetite, sphene and nepheline, often regularly arranged so as to give a zonal structure to the feldspar individual. The specific gravity of twelve small fragments of the feldspar of these large crystals, collected from a locality on the southern side of the mountain, and as free as possible from all inclusions, was determined. The specific gravity of nine of these lay between 2·59 and 2·607, while that of the other three was between 2·625 and 2·628. This shows the feldspar in the former case to be identical with that of the pulaskite, while in the latter three the specific gravity lies between that of albite and oligoclase. The somewhat greater specific gravity in this case may be due in part to inclusions of other minerals. A separation of the constituents of the rock shows, however, that, as

above mentioned, a considerable amount of oligoclase is really present. The feldspar individuals, both great and small, usually show in thin sections the mottled character due to the intergrowth of different species described in the pulaskite. A partial analysis of a specimen of this intermediate rock, from the south side of the mountain, is given in the table of analyses on page 73 (No. VI). As will be seen it is intermediate in chemical composition between the essexite and the pulaskite, occurring on either side of it, thus representing an intermediate zone in which the differentiation was not quite completed. It is, however, much more nearly allied to the essexite.

Essexite.—The rock is dark in colour and rather coarse in grain, and while holocrystalline, usually presents a more or less marked fluidal arrangement of the contituents. This is especially marked in the zone of transition between the essexite and the pulaskite, owing to the presence there of the large feldspar phenocrysts which, being arranged with their longer axes parallel to the direction of flow, serve to accentuate this structure. The finer grained variety forming the summit of the mountain is more massive in character and does not exhibit the fluidal arrangement of constituents. Under the microcsope the rock is seen to be composed of the following minerals: hornblende, pyroxene, biotite, olivine, plagioclase, nepheline, sodalite, apatite, magnetite, sphene, and in some cases a very small amount of orthoclase.

There is a marked tendency on the part of all the constituents to assume an idiomorphic development. The long lath-shaped plagioclases and large hornblende individuals have an approximately parallel arrangement, and between these lie the other iron-magnesia constituents with the smaller plagioclase individuals, the nepheline and the other components of the rock. These interstitial constituents do not differ greatly in size from the others, and show the same tendency to a parrallel arrangement.

Hornblende is present in almost every thin section of the rock along with pyroxene and biotite, but the relative proportion of these minerals varies considerably. The hornblende is distinctly the most abundant, except in the finer-grained variety forming the summit of the mountain, in which it is distinctly subordinate in amount to both pyroxene and mica. It is deep brown in colour and is sometimes hypidiomorphic in its development, but

often occurs with perfect crystalline form, showing the prismatic and the orthopinacoidal faces. Its extinction is larger than is usual in brown hornblendes, reaching 20°. It possesses a strong pleochroism. The hornblende in a state of perfect purity was analysed by Professor Norton-Evans, of McGill University. The results of the analysis are given below, together with those of several hornblendes of similar composition which have been added for purposes of comparison:

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
SiO_2	38·633	39·75	40·15	40·14	41·35	39·16
TiO_2	5·035	5·40	5·21	4·26	4·97	
Al_2O_3	11·974	15·00	14·34	14·30	13·48	14·39
Fe_2O_3	3·903	7·86	7·80	7·07	5·14	12·42
FeO	11·523	2·89	4·53	6·27	10·33	5·85
MnO	0·729			0·21		1·50
MgO	10·200	14·16	13·14	11·62	11·44	10·52
CaO	12·807	12·97	11·75	12·00	10·93	11·18
Na_2O	3·139	1·92	2·31	2·22	2·10	2·48
K_2O	1·489	1·61	1·14	1·35	0·62	2·01
H_2O	0·330				0·48	0·39
	99·762	101·56	100·37	99·44	100·84	99·90

No. 1.—Hornblende. From the essexite of Mount Johnson, Province of Quebec, Canada.
No. 2.—Hornblende. From Bohemian Mittelgebirge.
No. 3.—Hornblende. From tuff of hornblende basalt, Härtlingen, Nassau.
No. 4.—Hornblende. Basalt tuff, Hoheberg, near Giessen.
No. 5.—Hornblende. From "hornblende diabase," Graveneck, near Weilburg.
No. 6.—Hornblende. Syntagmatite. Jan Mayen.

The hornblende thus belongs to the class of basaltic hornblendes.

Pyroxene occurs intimately associated and often intergrown with the hornblende, both minerals frequently holding many inclusions of magnetite and apatite. It is pale greenish in colour, with no perceptible pleochroism, but with a marked dispersion of the bisectrices.

It is usually hypidiomorphic, but is frequently idiomorphic, showing a distinct cleavage parallel to the pinacoids, but usually none parallel to the prismatic faces. It belongs to the variety of diopside-like augites which occur in rocks of this class. The extinction is high, reaching 45°.

Biotite is deep brown, almost identical in colour with the hornblende and is strongly pleochroic. It occurs intimately associated with the hornblende and augite, and also frequently as a border around the iron ore. While usually present in comparatively small amount, in the finer grained essexite forming the summit of the mountain it is much more abundant than the hornblende. In this variety of the essexite both the mica and the hornblende often possess a poikilitic structure owing to the presence of numerous inclusions of plagioclase. The plagioclase also often penetrates the individuals of biotite and hornblende in the form of well developed crystals.

Olivine is found in the finer grained variety of the essexite at the summit of the mountain, and was also observed in the thin sections from the essexite at one point on the east side of the mountain not far from the summit. It is very pale green in colour and occurs as little grains inclosed in the biotite and pyroxene.

The *plagioclase* in the rock has well-developed, lath-like forms and is, almost without exception, excellently twinned according to the albite law. Twinning according to the carlsbad and pericline laws is also very common, occurring in the same individuals which show the albite twinning. The laths of plagioclase can in a few cases be seen to be distinctly twisted, evidently owing to pressure exerted upon them by other crystals during the consolidation of the rock, since the rock was subjected to no dynamic action subsequent to its crystallization.

As before mentioned, all the plagioclase individuals are not of the same dimensions. There are larger laths associated with the large hornblende crystals, and between these are smaller laths. The two sets are not, however, sufficiently well marked to cause the resulting structure to be classed as porphyritic. The plagioclase in the rock is not all of the same composition, but varies somewhat even in the same hand specimen, ranging from an extremely acid labradorite to an oligoclase. It, however, is chiefly andesine.

A very small amount of orthoclase is also present in some specimens of the rock, occurring as a subordinate accessory constituent.

Nepheline is quite subordinate to the feldspar in amount. It is sometimes quite fresh, but at other times is found more or less completely altered to a mineral which is either muscovite or kaolin. The nepheline is allotriomorphic and occurs chiefly in the corners between the larger crystals of feldspar and other minerals, and is penetrated by them. It is especially abundant in those portions of the rock which are rich in the dark coloured constituents. When occurring in this manner it appears, with the sodalite, to have been the last constituent of the rock to crystallize out. It is usually much more abundant than the sodalite. The nepheline also occurs in places as as irregular-shaped lath-like inclusions in the feldspar.

Sodalite is usually, although not invariably, present. It strongly resembles the nepheline in appearance and shows the same alteration product. Like the nepheline, it occurs either in the spaces between the other minerals, cementing them together, or as inclusions in the feldspars.

The abundance of *apatite* is a distinct feature in this as in similar rocks occurring elsewhere. It is always present and was the first constituent to crystallize out, being found in the form of perfect hexagonal prisms with double pyramidal terminations imbedded in the iron ore. It also occurs in the sphene as well as in the iron-magnesia constituents, in the nepheline, and also, although much less frequently, in the feldspar. Its large amount is shown by the high percentage of phosphoric acid in the analysis of the rock, 1·23 per cent. Another specimen of the rock in which the phosphoric acid was determined by Dr. B. J. Harrington gave 1·01 per cent. These figures represent 2·79 per cent. and 2·35 per cent. of apatite, respectively. It is usually somewhat turbid from the presence of minute dust-like inclusions.

Magnetite occurs chiefly inclosed in the iron-magnesia constituents, but is occasionally found in the feldspar. It is usually allotriomorphic, but occasionally presents an approximation to definite crystalline outline. As shown by the calculation of the analysis of the rock, this iron ore contains a considerable percentage of titanic acid.

Sphene is not found in more than one half of the specimens examined. When present it is not very abundant

and usually occurs as well defined, wedge-shaped crystals, often of considerable size.

In the accompanying table analyses are given of the normal essexite which forms the greater part of Mount Johnson, and of the finer grained, olivine-bearing variety of the same rock found at the summit of the mountain. For purposes of comparison there is presented in the same table the analysis of the essexite from Shefford mountain, which belongs to the same Monteregian province, together with analyses of the original essexite from Salem, Mass., and of allied rocks from two other localities. A partial analysis of the transitional rock between the essexite and the pulaskite of Mount Johnson is also given. The analysis of the Mount Johnson essexite (No. I) as well as for that of the associated pulaskite, which is given below, was made by Professor Norton-Evans, while the analysis of the olivine-bearing variety of the essexite (No. II) was made by Mr. M. F. Connor.

	I.	II.	III.	IV.	V.	VI.
SiO_2	48·85	48·69	53·15	46·99	47·67	50·40
TiO_2	2·47	2·71	1·52	2·92		1·17
Al_2O_3	19·38	17·91	17·64	17·94	18·22	
Fe_2O_3	4·29	3·09	3·10	2·56	3·65	5·58
FeO	4·94	6·41	4·65	7·56	3·85	
NiO+CoO	not det.	0·05	not det.	not det.		not det.
MnO	0·19	0·15	0·46	trace.	0·28	0·77
MgO	2·00	3·06	2·94	3·22	6·35	
CaO	7·98	7·30	5·66	7·85	8·03	6·77
BaO		0·08	0·13	none.		
Na_2O	5·44	5·95	5·00	6·35	4·93	6·24
K_2O	1·91	2·56	3·10	2·62	2·97	2·56
P_2O_5	1·23	1·11	0·65	0·94		0·09
Cl	not det.	not det.	0·07			
H_2O	0·68	0·95	1·10	0·65	3·82	
Total	99·36	100·02	99·84	99·60	100·15	

I.—Normal essexite (andose), Mount Johnson, Quebec.

II.—Olivine-bearing essexite (essexose), Mount Johnson, Quebec.

III.—Essexite (akerose), Shefford mountain, Quebec, (American Geologist, 1901, p. 201), (with CO_2 0·39 and SO_3 0·28).

IV.—Essexite (essexose), Salem Neck, Salem, Mass. (Washington, Jour. Geol., 1899, p. 57).

V.—Theralite, Elbow creek, Crazy mountains, Montana.

VI.—Rock forming transition from essexite to pulaskite, Mount Johnson, Quebec. (Partial analysis. The iron present is all calculated as FeO.)

The analyses (Nos. I and II) of two varieties of the essexite from Mount Johnson can be readily calculated out so as to show the quantitive mineralogical composition of the rocks.

The calculation of the mode*—or relative proportion of the minerals actually present gives the following result:

	Essexite (Analysis I.) Mount Johnson		Olivine-essexite (Analysis II.) Mount Johnson.	
Albite	36·75		29·14	
Anorthite	20·23	66·45	13·11	54·79
Orthoclase	9·47		12·54	
Nepheline	3·99		11·12	
Kaolin	·78	4·77	·78	11·90
Pyroxene		6·29		12·22
Hornblende		7·05		2·30
Biotite		2·04		4·08
Olivine		none.		2·84
Magnetite	5·68		3·94	
Ilmenite	3·85	9·53	4·47	8·41
Apatite		2·68		2·59
Water (hygr.)		·58		·85
		99·39		99·98

The calculation further demonstrates that the plagioclase in the case of No. I is a trifle more basic, and in the case of No. II a little more acid, than Ab_2 An_1, which, as has been stated, is shown by the optical character and by the specific gravity of the feldspar to represent its average composition in these rocks.

The small amount of orthoclase recognized in thin sections also appears as mentioned in the description of the rock. The nepheline is in places somewhat altered to a mineral resembling kaolin. The small percentage

*Quantitative Classification of Igneous Rocks (C.I.P.W.) (University of Chicago Press, 1903), p. 147.

of kaolin shown by the calculation has therefore been added to the nepheline in extending the table.

No. I takes the following position in the Quantitative Classification:

Class II, Dosalane.
Order 5, Germanare.
Rang 3, Andase.
Subrang, 4, Andose (grad—polmiric.)

No. II, however, belongs to the next order and is domalkalic. Its position in the Quantitative Classification is as follows:

Class I,, Dosalane.
Order 6, Norgare.
Rang, 2, Essexase.
Subrang 4, Essexose (grad—prepolic).

It is therefore seen that the essexite from the central portion of Mount Johnson (No. II) is practically identical in character and composition with the essexite of the original locality of Salem, Mass. (Analysis IV), while the outer andose is poorer in nepheline and has a somewhat larger proportion of lime as compared with the alkalies.

Dykes—A feature in connection with Mount Johnson, and one possibly connected with its somewhat peculiar structure, is the almost entire absence of dykes. Only five small dykes, each only a few inches wide, have been found. Some of these are camptonite, while the others, although much altered, are apparently solvsbergite.

Structure—The structure of the mountain and the character of the rocks composing it throw some light on the question as to where the differentiation took place. In course of conversation with the foreman of one of the quarries in the essexite on the flank of the mountain, the writer was informed by him that Mount Johnson consisted of three layers of horizontal rock; a fine grained one on top, below which was the coarser grained rock of the quarry, and beneath this a spotted variety. Each of these layers, he considered went through the mountain horizontally and could be seen outcropping at their respective levels on every side. The three rocks referred to were, as will be recognized, the fine grained essexose, the andose, and the transitional rock below the latter, respectively. The pulaskite zone he had not noticed, it being at the base of the mountain and in many places more or less covered

with fallen blocks and talus. If this were the true interpretation of the structure, the mountain would have to be considered as the remnant of a laccolite which had been intruded between the horizontal Silurian strata and which had subsequently been almost entirely removed by peripheral denudation. This has been shown to be the true explanation of the origin of some of the occurrences,



Andose in quarry on Mount Johnson, showing vertical flow structure.

formerly supposed to be intrusive stocks, in the western portion of the United States, and it was at first considered as a possible explanation of the origin of MountJohnson. A careful examination of the mountain, however, shows that such an explanation of its origin is untenable, and that it is a true neck, due to the filling up of a nearly circular perforation in horizontal strata by an upward moving magma.

The evidence of this is to be found in the direction of the banding or fluidal arrangement of the crystals in the essexite already referred to and shown in the accompanying illustration. This fluidal arrangement is seen in most large exposures of the essexite and with especial distinctness in the great faces of this rock exposed in the quarries on the mountain side, and it is always vertical, showing that the movement of the rock was upward through the pipe, and not outward and horizontally over the pulaskite, as it would have been in the case of a laccolite. Furthermore, in several cases when the fluidal arrangement is very distinct and has a somewhat banded character due to the alternation of somewhat more feldspathic portions of the rock with others richer in iron-magnesia constituents, a strike can be made out on horizontal surfaces, and this strike curves around the mountain, following its marginal outline, as shown on the map.

It is thus clear that Mount Johnson is a neck in its most typical form. A cross-section of the mountain is shown in the accompanying figure. The opening occupied by the intrusion was, in all probability, formed by the perforation of the horizontal shales at this point by the explosive action of the steam and vapours preceding the eruption proper, as it presents exactly the features reproduced by Daubrée in his highly suggestive experiments on the penetrating action of exploding gases. It is, in fact what he terms a *diatrème.*

"Des perforations aussi remarkables, tant par leurs formes que par les communications qu'elles ont établies avec les profondeurs du sol, constituent, parmi les cassures terrestres, un type assez nettement charactérisé pour mériter d'être distingué par une dénomination précise et cosmopolite. Le nom de diatrème rapelle l'origine probable de ces trouées naturelles, véritables *tunnels verticaux*, qui se rattachent souvent, comme un incident particulier, aux cassures linéaires, diaclases et paraclases.*"

The occurrence is one which presents a close resemblance to the remarkable volcanic necks described by Sir Archibald Geikie** in East Fife, and also to those described by Branco†, in Wurtemberg. Mount Johnson, however, is a neck occurring in an area which has undergone much

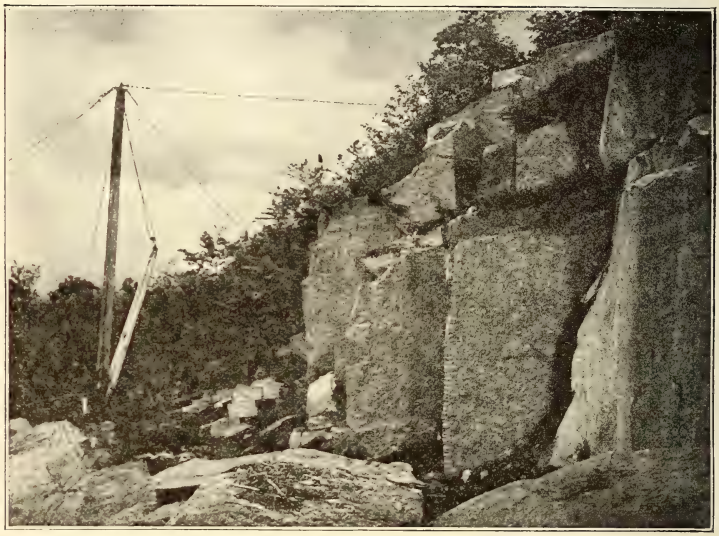
*"Recherches expérimentales sur le rôle possible des gaz à hautes températures doués de très fortes pressions, etc.," Bul. de la Soc. Géol. de France, 3e série, tome XIX. (1891) p. 238.

**The Vocanic Necks of East Fife. Glasgow: Hedderwich & Sons.

†Schwabens 125 Vulcan-Embryonen und deren tufferfüllte Ausbrurhsröhren das grösste Gebiet ehemaliger Maare auf der Erde. Tübingen, 1894.

more extensive denudation since the time of the intrusion than in the cases above mentioned, and as a consequence of this, the fragmental material which fills some, although not all, of the necks referred to above, has been entirely swept away.

In view of the fact, then, that Mount Johnson is a neck or pipe of comparatively small sectional area, in which the differentiation is very complete, but in which the magma did not remain at rest, but was moving upward



Quarry in andose, Mount Johnson, showing vertical flow structure (on right).

long prior to final consolidation, it seems improbable that the marked differentiation of the magma into the several varieties took place while the magma was in the pipe itself. The evidence points rather to the differentiation of the mass having already taken place in the reservoir of molten rock beneath, which was tapped by the pipe. If this be the case, it would seem that the upper and more acid portion of the magma, represented by the lighter pulaskite, had collected in the upper portion of the reservoir, and that the essexite formed a lower, more basic, and heavier

stratum or part. When the passage to the surface was opened up, the pulaskite would first rise in it, and, after a more or less continued flow, being followed by the essexite, would be pressed toward the circumference of the pipe, the more basic rock occupying the central portion of the passage, and the most basic variety, originally, lower would be found in the central axis of the neck. The fact that, while the essexite forms the mass of the intrusion, there is a zone of pulaskite about it, would seem to indicate that there had not been at this centre of volcanic activity any very protracted outpouring of the essexite, since, had this been the case, it would seem probable that the pipe would have, in time, been cleared of the upper pulaskite magma.

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EXCURSION A 8.

MINERAL DEPOSITS OF THE OTTAWA DISTRICT

BY

J. STANSFIELD.

CONTENTS.

	PAGE.
Introduction	82
Scope of excursion	82
General geological description	82
Pre-Cambrian	82
Ordovician	84
Pleistocene and post-Pleistocene	85
Annotated guide	86
The apatite deposits at the Emerald mine	89
Local geology	89
Character of the apatite deposits	90
Petrographical notes	91
Sillimanite gneiss	91
Biotite granulite	91
Muscovite-biotite-gneiss	91
Limestone	92
Hypersthene granite	92
Garnetiferous gneiss	92
Gabbro	93
Annotated guide (continued)	93
The Eozoon occurrence at Côte St. Pierre	95
Geological relationships	95
The nature of Eozoon canadense	98
Historical outline	99
Annotated guide (continued)	99
The graphite deposits at the Walker mine	101
General geology of the locality	101
Geological relationships of the graphite deposits	101
Annotated guide (continued)	105
The graphite deposits at the Dominion mine	105
Annotated guide (continued)	107
The mica deposits at the Nellis Mine	111
Geological relationships of the deposits	111
Character of the veins	111
Annotated guide (continued)	113
Bibliography	114

INTRODUCTION.

Scope of Excursion.

This excursion has for its objective an occurrence of Eozoon canadense and certain deposits of apatite, graphite and mica which lie within the southern edge of the Pre-Cambrian region immediately north of the Ottawa river. These deposits, while of minor economic importance and supporting only small and precarious industries, are nevertheless of considerable geological interest. Leaving Montreal by rail the excursion will follow the north shore of the Ottawa river to Ottawa, short northward trips being made from Papineauville to the Eozoon locality at Côte St. Pierre, from Buckingham to the apatite deposit at the Emerald mine and the graphite deposits at the Walker and Dominion mines, and finally from Ottawa to the Nellis mica mine at Cantley.

General Geological Description.

The geology of the region to be traversed admits of a clearly marked three-fold subdivision:

3. Pleistocene and Post-Pleistocene.
 - c. Saxicava sand.
 - b. Leda clay.
 - a. Boulder clay.
2. Ordovician.
 - f. Utica.
 - e. Trenton.
 - d. Black River.
 - c. Chazy.
 - b. Calciferous.
 - a. Potsdam.
1. Pre-Cambrian.
 - c. Anorthosites.
 - b. Ottawa gneiss (granite, diorite, gabbro.).

Pre-Cambrian. The oldest Pre-Cambrian rocks in the region to be visited are a series of highly metamorphosed sedimentary materials, probably the oldest rocks in eastern North America, to which the name Grenville series was first applied in this region [**19**]. These are intruded by immense bodies of granite, diorite and gabbro, collectively known

as the Ottawa gneiss, and by a younger group of intrusive anorthosites.

As may be seen by referring to the Grenville map-sheet, the Grenville series occupies only a small percentage of the Pre-Cambrian area. It outcrops in long, narrow bands from one half to one mile (·8 to 1·6 km.) wide, that have a general strike of N. 30° E., although this varies in places to north, and even to west of north. That the series has been subjected to intense pressure is shown by the strong and complicated folding which has taken place, and can be beautifully illustrated even in small specimens. An example of this is to be seen on the north shore of the Ottawa river at Papineauville. The Grenville series is composed of gneisses which have the chemical composition of clay slates, though now so completely metamorphosed, that they retain no sign of their original character. These include many areas of black and rusty-weathering gneisses, with compositions intermediate between those of sandstones and clays, which probably represent original sediments of the Grenville series. Some sillimanite gneisses of this type have been examined and proved to be sediments. Others have indefinite characters which do not allow of a decision as to their sedimentary or igneous origin. A few unimportant bands of quartzite are also encountered, but limestone is by far the most important member of the series. The limestone is very impure. It varies from white crystalline marble to brown, and in composition from limestone to magnesite. Where the latter rock is quarried in Grenville township, the best analyses published show not less than 10·5% of $CaCO_3$. Silicates are common impurities in the limestone, pyroxene and phlogopite, being the most abundant. All the minerals found in the limestone of this district are included in a list of such minerals occurring in the Grenville series in the Haliburton and Bancroft areas that is given by Drs. F. D. Adams and A. E. Barlow [**20**].

These two geologists have shown that the Grenville series, in the above mentioned area, attains a thickness of 17·88 miles, (28·6 km.), or 94,406 feet (28,782 m.), of which thickness 53·35% is limestone. They have also shown that the coarsely crystalline limestones or marbles of the series have been derived from blue limestones of a normal sedimentary type by thermal metamorphism attendant upon their intrusion by immense batholiths of igneous material

[**20**]. That pressure also has played some part in this metamorphism cannot be doubted, but the major part is undoubtedly due to contact action. The same applies to the metamorphism displayed by the limestones in the area to be visited, But here we are unable to compare the metamorphosed limestone with the normal, the latter being hidden from view south of the Ottawa river by a thick covering of Palæozoic sediments.

The Grenville series is intruded by a great suite of granite and syenite batholiths, with subordinate diorites and gabbros which are included under the name Ottawa gneiss [**21**]. As a general rule the granites are older than the diorites and gabbros. The gabbros show all variations of composition from anorthosite to pyroxenite. In the small areas to be visited, typical granites are not well instanced. The oldest intrusives have characters which closely ally them with the charnockites of southern India. Later intrusives usually have the characters of diorite or gabbro. All of these have a more or less strongly marked gneissic structure, and are cut by many pegmatite veins. A younger set of gabbros, in which gneissic structure is typically absent, has been responsible for the formation of the ore-bodies to be visited. These are sometimes cut by a younger set of pegmatite dykes, which often possess peculiar characteristics.

The youngest of all the intrusives, in the areas to be visited, are diabase dykes, which reach a thickness of 60 feet (18·3 m.) or more, and can often be traced across country for many miles. Eastward, beyond the special areas to be visited, are large areas of anorthosite, the youngest of all the Pre-Cambrian intrusives.

Ordovician.—The earliest member of this group is the Potsdam sandstone. It rests unconformably upon the Pre-Cambrian, and is followed conformably and sometimes overlapped by the Calciferous sandy dolomite, which in turn is followed by the other members of the Ordovician system. The Potsdam sandstone is often quartzitic, and lacks definite fossils by which it may be correlated with the Potsdam to the south, which, in Wisconsin and elsewhere, contains the Dicellocephalus fauna. Up to the present worm-burrows and brachiopods are the only fossils found in the Canadian Potsdam. It seems probable that it represents the continuation, during the earliest Ordovician time, of the submergence of the North

American continent, with an attendant northward recession of the coast-line, which began in Upper Cambrian time.

In the western part of the district under consideration, Palæozoic sediments occur south of the Ottawa river, with only a narrow strip along the northshore, while in the eastern part a broader band of them separates the Pre-Cambrian margin from the Ottawa. They lie in almost the same attitude as when they were laid down, having a slight dip to the south or south-east. Further to the south-east, intense folding has taken place in Palæozoic and later times, but in this region, where the Palæozoic may be regarded as a very thin cover on the Pre-Cambrian floor, the latter is responsible for the absence of folding. The Pre-Cambrian acted as a buffer against which the Appalachian folds were thrust, and suffered no folding itself, consequently the thin Palæozoic crust on its surface remain untilted. Nevertheless the Palæozoic rocks have suffered from dislocation, faults being traceable sometimes for long distances across country; for example, the Hull and Gloucester fault, mentioned below. In the vicinity of Ottawa the Palæozoic rocks are much broken up by faults.

Pleistocene and Post-Pleistocene.—A great hiatus exists between the Palæozoic and Glacial periods in this part of Canada. For the greater part of the time represented by this hiatus the region formed a part of the land surface of North America. The Glacial period has left its record in the boulder clay, which has the usual characters of this rock, and which does not allow of any subdivision in this area. Subsequent to the retreat of the ice, but while large masses of ice still covered the country to the north and maintained an arctic climate, the lower part of the St. Lawrence valley was below sea-level. This was probably due to the weight of the great bodies of ice, still existent to the north. The sea occupying this estuary extended almost as far as Kingston. An arm extended down the Champlain valley, probably connecting with the Atlantic by way of the Hudson valley. Another arm reached up the Ottawa river beyond Ottawa. This arm had smaller bays running up the Gatineau, Lievre, and Nation rivers and other tributaries of the Ottawa river. Into this marine arm was emptied large quantities of "rock-flour" brought by the streams from the ends of

the glaciers, and doubtless, in part too, within the ice that floated away as icebergs. This fine mud was laid down upon the floor of the sea. Recurrent slight differences in its composition gave rise to a fine lamination which can often be seen in exposures of Leda clay, as these marine sediments are called. The shells found in the clay indicate that the climate of that time was similar to the present climate of the Labrador coast. At Green's creek, near Ottawa, the clay is rich in calcareous nodules which have yielded many fossils, especially *Mallotus villosus*, (Cuvier) and other fishes.

The Leda clay is overlain by the Saxicava sand which was laid down as the sea shallowed and withdrew to its present level. The Saxicava sand is often crowded with shells of *Saxicava rugosa*, Lamarck, though extensive areas may be examined without discovery of a single shell. That the emergence of the land took place in stages is shown by the successive terraces of the lower St. Lawrence, nowhere better shown than on the flanks of Mount Royal, where as many as seven raised beaches, indicating successive halts in the gradual elevation of the land, have been recorded by Sir J. W.Dawson [**24**]. The most conspicuous of these seen in passing along the Ottawa valley is the 220 foot (67 m.) terrace, known at Montreal as the Waterworks terrace. It is constantly in view, especially to the north of the railroad.

ANNOTATED GUIDE.

Miles and Kilometres.

0·0 m. **Montreal** (Place Viger)—Alt. 57 ft. (17·4 m.).

12·8 m. 20·5 km. **St. Martin Junction**—Alt. 110 ft. (33·5 m.).

32·5 m. 52·0 km. **Ste. Scholastique**—Alt. 238 ft. (72·7 m.).

44·2 m. 70·8 km. **Lachute**—Alt. 229 ft. (69·7 m.).

57·6 m. 92·0 km. **Grenville**—Alt. 210 ft. (64 m.).

79·1 m. 126·8 km. **Papineauville**—Alt. 149 ft. (45·5 m.).

83·9 m. 134·3 km. **Plaisance**—Grenville limestone is exposed in the railroad cutting west of Papineauville. Beyond this a granulite batholith, composed in part

Miles and Kilometres.

of a granite which shows no evidence of having undergone pressure, is seen. At first the rounded glaciated surfaces are abundant, but toward and beyond Plaisance they are less numerous, being covered by Leda clay and Saxicava sand. The sea-cliff, which has been noted in the introductory statement, is frequently visible.

90·6 m. 144·8 km. **Thurso.**—Alt. 186 ft. (56·7 m.). The same conditions continue west of Plaisance, the Pre-Cambrian margin now approaching the railway, now receding for half a mile. Between Thurso and Lochaber the sea-cliff is well-marked.

94·0 m. 150·4 km. **Lochaber.**—At Lochaber there are a few small exposures of well-banded gneiss immediately north of the railway, but from here to Buckingham Junction the Pre-Cambrian margin is again covered.

100·0 m. 160·5 km. **Buckingham Junction**—Alt. 183 ft. (55·8 m.). The journey from Buckingham Junction to Buckingham affords little of interest to the geologist. The road runs over Leda clay to the sea-cliff, which it climbs. Along the upper level, also the index of a former sea-level, the view is interrupted by thick bush. Occasionally the capping of Saxicava sand is visible. Pre-Cambrian exposures occur in Lievre river to the west, but are nowhere visible from the road.

103·0 m. 165·0 km. On the right-hand side of the road, immediately north of the Alexandra hotel at Buckingham, crystalline Grenville limestone is cut by a gabbro dyke. These two are the most important rock types exposed in and around Buckingham. The limestone is part of a band, having a general north-east trend, and the gabbro is important, both as dykes and as larger intrusions. West of the road, at the slight rise where it leaves the town, is a mass of this gabbro. The most important exposures for two miles (3·2 km.) north of Buckingham are of this same type of gabbro. At the bank of the river is a much altered limestone, and limestone is again seen east of the road and the railway.

Miles and Kilometres.

104·6 m. 167·8 km. A cliff of gabbro extends along the east side of the road, while, on the west side are black-weathering gneisses of doubtful origin cut by pegmatite veins. These veins do not cut the gabbro on the east side of the road.

107·4 m. 172·0 km. Thin-banded gneisses on both sides of the road have small areas of limestone associated with them. To the left of the road they are cut by a 40-foot (12·2 m.) diabase dyke belonging to the youngest series.

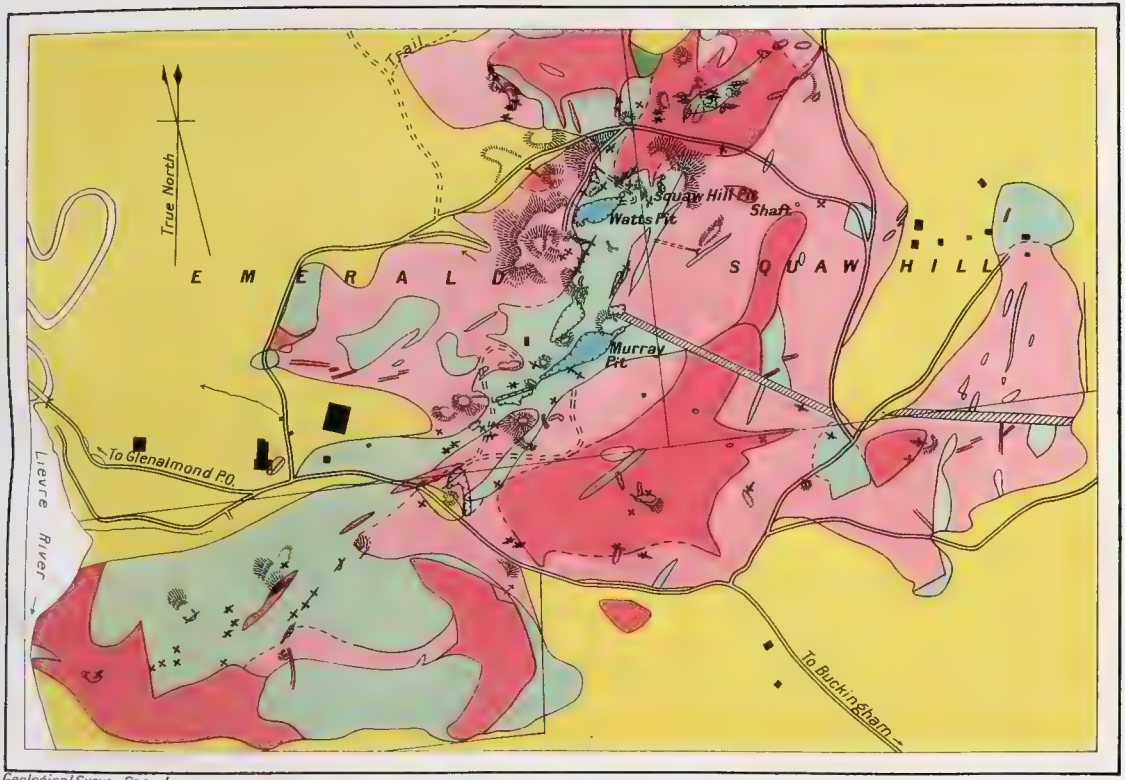
108·5 m. 174·0 km. The cliff to the right of the road is composed of well banded gneisses cut by pegmatite dykes. Some of the gneisses appear to be altered sediments. One of these gneisses at the south end of the hill has been prospected for graphite, of which it contains a little. Another prospect in the face of the hill shows ore connected with a dyke of gabbro, very similar in appearance to that found at the Dominion mine. Immediately beyond the next small creek, rises a hill, faced towards the road with Grenville limestone. On the top of this hill is an old prospect, where columnar graphite occurs at the contact of pegmatite and Grenville lime stone.

109·5 m. 175·0 km. For three-fourths of a mile (1·2 km.) north of this, black-weathering gneisses, mainly of igneous origin, and much cut by pegmatites, which also weather black, are exposed on either hand.

111·4 m. 178·0 km. The hill on the west side of the road consists of granite gneiss at the southern end, becoming dioritic toward the north. Across the road are gneisses, similar to the hypersthene-granite-gneisses at the Emerald mine and containing the same garnetiferous bands.

113 m. 181 km. Leda clay with its capping of Saxicava sand, extends from here to the Emerald mine.



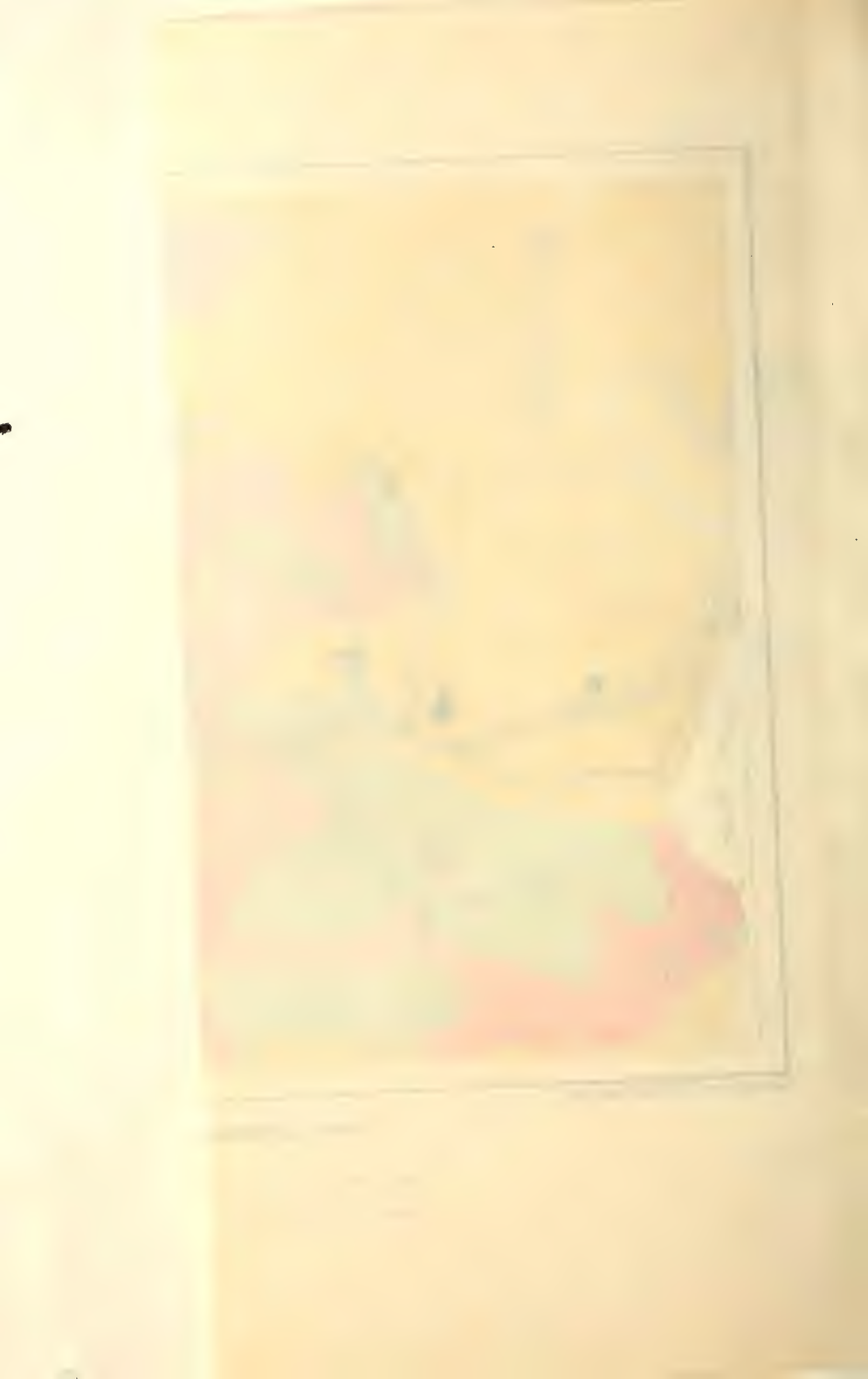


Geological Survey, Canada.

Emerald Mine, Buckingham Township, Quebec

Feet
100 0 400 800 1200

Metres
100 0 100 200 300



THE APATITE DEPOSITS AT THE EMERALD MINE.

Local Geology.

The hill containing the Emerald and Squaw Hill groups of mines rises abruptly from the plain of Leda clay and abuts on the left bank of Lievre river. This proximity to the river facilitated shipmen of the phosphate by water to Buckingham, when the mines were producing.

Grenville limestone, the oldest of the rocks found in this locality, is represented by small remnants of much altered and very impure limestone. Garnetiferous and sillimanite gneisses situated west of the main occurrences of gabbro may represent an argillaceous phase of the Grenville series, though richness in aluminous silicates is about the only evidence of their sedimentary nature. The older gneisses to the east of the gabbro area are for the most part hypersthene-granites rich in quartz. They include garnetiferous bands, and often garnet entirely replaces the pyroxenes, resulting in rocks comparable to the leptynites of French authors. These rocks so closely resemble the charnockites of southern India in their general character and age, that the name charnockite is applied here, due weight being given to Holland's warning regarding the application of this term outside of India.

The older rocks of the above groups have been intruded by binary granite, and again by a younger series of gabbros and diorites, of which the last named often have the form of lenticular dykes. After microscopical study, there appears to be no reason for differentiating these gabbros from each other. Therefore they have received one colour on the map. A later series of pegmatites has cut these and all older rocks, and the pyroxenite dykes carrying the apatite deposits are later than the pegmatites. It has been usual in the past to associate the pyroxenite dykes with the gabbros above mentioned and no evidence contradictory to this opinion has appeared as yet; hence it is probable that these later pegmatites are closely connected in origin with the gabbros, perhaps as acid and basic differentiation products of one parent magma.

The youngest Pre-Cambrian rock in the area is a 50 foot (15·2 m.) dyke of olivine-diabase, which cuts all

other rocks indifferently. There is a small area of peridotite on the hill west of the main road whose relations to the other rocks, and age are not discernible. The rock has the characters of a wehrlite.

Character of the Apatite Deposits.

There is a large number of small apatite veins in the hill, but only a few large ones. The smaller veins beautifully illustrate the banded vein structure. Their walls are usually definite and rectilinear, and are covered with a dark green to black comb of pyroxene crystals, light grey granular pyroxene or an aggregate of pyroxene and scapolite. Ordinarily this external layer is not more than a few inches wide. The central part of the vein is filled with apatite or with apatite surrounding a central band of slightly pink calcite, in which are embedded perfectly shaped apatite crystals. The apatite is a green fluor apatite. In the large veins granular masses of "sugar" apatite, which could often be shovelled out without blasting, are more common than the crystalline form. Pyrite and pyrrhotite occur in some of the veins, pyrite being abundant enough in some instances to lower the market value of the mine product. Actinolite has been found only on the dumps. The many and rare minerals associated with similar deposits in Templeton township do not occur here. Rapid local increases in the width of a vein give rise to pockets in which, however, the parallel vein structure persists. Some of these pockets have been worked out to a depth of 50 feet (15·2 m.). Deposits of this type were worked at the Murray, Watt, Boileau and Squaw Hill pits. The pyroxene-scapolite rock is the only vein material that needs description. This veinstone contains, besides pyroxene and scapolite, small quantities of secondary hornblende derived from the pyroxene, tremolite, biotite, titanite, pyrite, calcite, apatite, and aggregates of small mica flakes, which have resulted from decomposition of scapolite. The scapolite has a birefringence which places it nearer to meionite than mariolite. Pyroxene is usually more abundant than scapolite, but examples occur which deserve the name scapolite-gabbro.

The close association of the apatite-bearing veins with the gabbro implies a genetic connection. In further support of this, specimens of gabbro have been collected

which contain pockets of apatite about the size of the fist, evidently a constituent of the rock and not displaying banding or vein structure. Apatite-bearing veins cut pegmatites near Watt's pit, on the Lansdowne property south of the main road, and in the north-east corner of the map area.

Petrographical Notes.

Silimanite-gneiss.—Samples of this rock from the northern part of the hill contain a strongly pleochroic, brown biotite as their principal coloured constituent. This mineral occurs in ragged grains and is often micro-poikilitically intergrown with feldspar. Fanlike aggregates are also common. Sillimanite occurs in large grains or as fine needles, at the boundaries between feldspar individuals. Feldspar, including orthoclase and microcline, is an important constituent and is often crowded with inclusions of fine, opaque needles. Quartz, which is subordinate in amount to feldspar, is rich in similar inclusions. The accessory minerals include a small amount of muscovite, zircon—with pleochroic halos when surrounded by biotite —pyrite, leucoxene, and in one case garnet. The pressure to which the rock has been subjected is indicated by strain-shadows in the quartz and feldspar, and by the incipient "mortel-structure," developed more especially in the case of feldspar.

Biotite granulites from the same locality are rich in pink garnets which often have borders of ragged biotite. Brown, strongly pleochroic biotite, orthoclase and microcline are the other essential constituents. Micro-perthite is sparingly represented, and quartz is subordinate in amount to feldspars. Accessory constituents include round grains of zircon, a rich sprinkling of dark brown rutile and very little apatite and pyrite. Strain-shadows are seen in the quartz. Microscopic examination is sufficient to determine whether this is an altered sediment. or of igneous origin.

Muscovite-biotite-gneiss from the same part of the hill consists almost wholly of micas, the biotite being brown and intensely pleochroic. Quartz, a very little orthoclase and some plagioclase are also present, and zircon occurs as an accessory.

Collectively, these gneisses present evidence of being a series of altered sediments, though if each one were considered separately, it would be difficult to arrive at any definite conclusion regarding its origin.

An altered limestone from the tunnel on the south face of the hill, contains in addition to calcite a green, slightly pleochroic pyroxene, some scapolite and large rounded grains of pink titanite.

Gneiss from the north-east part of the map area has pink titanite as its most important coloured constituent, though biotite and hornblende are also present. Orthoclase and microcline are the two most important constituents; quartz, plagioclase, scapolite and calcite are less important. A very small amount of the quartz is intergrown micrographically with the feldspar. The rock possesses a well-developed gneissic structure due to a parallel arrangement of the mica flakes, to the "mortel-structure," more especially of the feldspars and to the strain-shadows in the quartz. The scapolite shows no evidence of strain-shadows, or granulation, which would indicate that this mineral had been formed subsequently to the application of pressure, or as a result of its application. The micrographic intergrowth of quartz and feldspar indicates an igneous origin for this rock.

Hypersthene-granite (*charnockite*), typical of the southern part of the hill, is characterized by considerable amounts of strongly pleochroic hypersthene and pink garnet, and a large amount of quartz. In fact, this latter mineral is the only one that catches the eye in weathered hand-specimens. Plagioclase is more important than orthoclase, but both are much subordinate to quartz. Brown biotite and zircon are the only other constituents. The quartz is granulated and both quartz and feldspars show strain effects.

Garnetiferous gneiss. Associated with the hypersthene-granite are quartz and pegmatite veins, and bands of garnet-gneiss, which may be related to the hypersthene-granite in the same manner as similar rock-types are related to the charnockites of southern India. Pink garnet, the most important constituent of this gneiss is very conspicuous in the hand-specimen. It often contains biotite or feldspar inclusions. Brown biotite, an important constituent, has crystallized after the garnet. Orthoclase is much the most important feldspar, though microcline, plagioclase and microperthite are also present. The





Geological Survey, Canada

Route map between **Papineauville** and **Côte St Pierre**

Feet
1000 0 4000 8000 12000
Metres
1000 0 2000



feldspars are crowded with minute inclusions of opaque rods. Ilmenite, with leucoxene borders, apatite, and zircon are accessory constituents.

Gabbro. A specimen of gabbro from the south side of Murray's pit contains a considerable quantity of green hornblende, and of colourless augite surrounded by primary reaction rims of hornblende. There is also a small amount of strongly pleochroic hypersthene. The subordinate remaining portion consists of plagioclase which alters both to scapolite and to paragonite. The rock is a hornblende-hypersthene-gabbro. Osann has described a rock from the same place which carried enstatite instead of hypersthene [**2**].

Exposures of gabbro at the northern edge of the hill differ from this in that they hold reddish-brown biotite and a monoclinic pyroxene having the pleochroism of hypersthene. Some sections of the pyroxene extinguish obliquely at angles like those of augite, while others have straight extinction, and in some sections the former have a slight greenish colour which serves to distinguish them from the latter. It seems likely, therefore, that a part of the pyroxene is hypersthene.

Other exposures near the margins of the hill, more especially on the south and west sides, are intermediate between the gabbro of the centre of the hill and the diorites at the extreme borders. They show the same derivation of hornblende from augite and in some cases a notable amount of primary epidote. Hypersthene is absent, however. Scapolite is a common mineral in these rocks, and in the peripheral diorites.

ANNOTATED GUIDE—(Continued).

Miles and Kilometres.

79·1 m. 126·8 km. **Papineauville**—Alt. 149 ft. (45·4 m.). North of the track at Papineauville railway station is a section showing the relation of the Grenville limestone to other members of the Pre-Cambrian. The limestone which is banded, dips east 65° and strikes N. 42° E. magnetic. Intercalated with it, as illustrated in the accompanying section, is a dioritic gneiss, in part altered to a mica-schist, and also, a more distinctly intrusive binary granite.

Miles and Kilometres.

79·5 m. 127·2 km. The extremely close folding sometimes seen in the impure Grenville limestones, is well shown by an exposure in the bank of the Ottawa river. At 200 feet (61 m.) north of the river bank, a dyke of binary granite, 200 feet (61 m.) wide and continuous with that seen at the railway station, cuts the limestone.



Section in the Pre-Cambrian at Papineauville, Que., north side of railroad.

The slight rise from the river to the level of the village is due to the same sea-cliff which was noticed from the train. Its capping of Saxicava sand is very evident in the streets of the village.

80 m. 128 km. On turning north from the village, exposures of coarsely crystalline Grenville limestone, cut by pegmatite dykes, occur along the road. A broad band of this limestone, more especially developed on the east side of the road, is cut at many places by pegmatite dykes and also by dykes which may be called gabbro-pegmatite.

80.4 m. 128.5 km. A band of richly garnetiferous gneiss is visible on the right side of the road, and farther to the west are exposures of a granulitic batholith, which extends in the direction of Plaisance. The garnet-gneiss is followed by a tongue of the granulite, and this by another small exposure of richly garnetiferous gneiss.

80.8 m. 129.5 km. Leda clay covers the succeding flat area, exposures of the granulite occurring to the west and of limestone to the east.

82 m. 131.5 km. Grenville limestone cut by pegmatite dykes is seen to the right of the road.

82.6 m. 132.2 km. The Leda clay has a slight capping of Saxicava sand.

Miles and Kilometres.

83 m. 133 km. A local pebble beach of the Saxicava sea causes a slight topographic change. Exposures of limestone are passed on either hand, and North Nation river is crossed.

84 m. 134.5 km. The road follows the north bank of the river, skirting a cliff of granite-gneiss, with which are associated a few minor bands of limestone.

85 m. 136 km. On both sides of the road Ottawa gneiss of granitic character is exposed. At the turn and rise in the road a binary granite is seen on the left, which obstructs Nation river, causing a fall, the power from which is utilised by a hydro-electric station. After leaving the exposures of granite-gneiss at the top of the hill the road follows a band of Leda clay, through which granite is occasionally exposed at distances of one fourth to one half of a mile (.4 to .8 km.) from the road.

86 m. 137.6 km. A biotite-tourmaline-granite, typical of the area extending from Nation river to St. André Avelin, is here exposed.

88.6 m. 141.8 km. A few exposures of impure, banded limestone are observable near St. André Avelin.

89 m. 142.4 km. Re-crossing North Nation river, the road follows its east bank, in which Leda clay is

92 m. 147.5 km. sometimes exposed beneath a thin capping of Saxicava sand. This continues until Côte St. Pierre is reached.

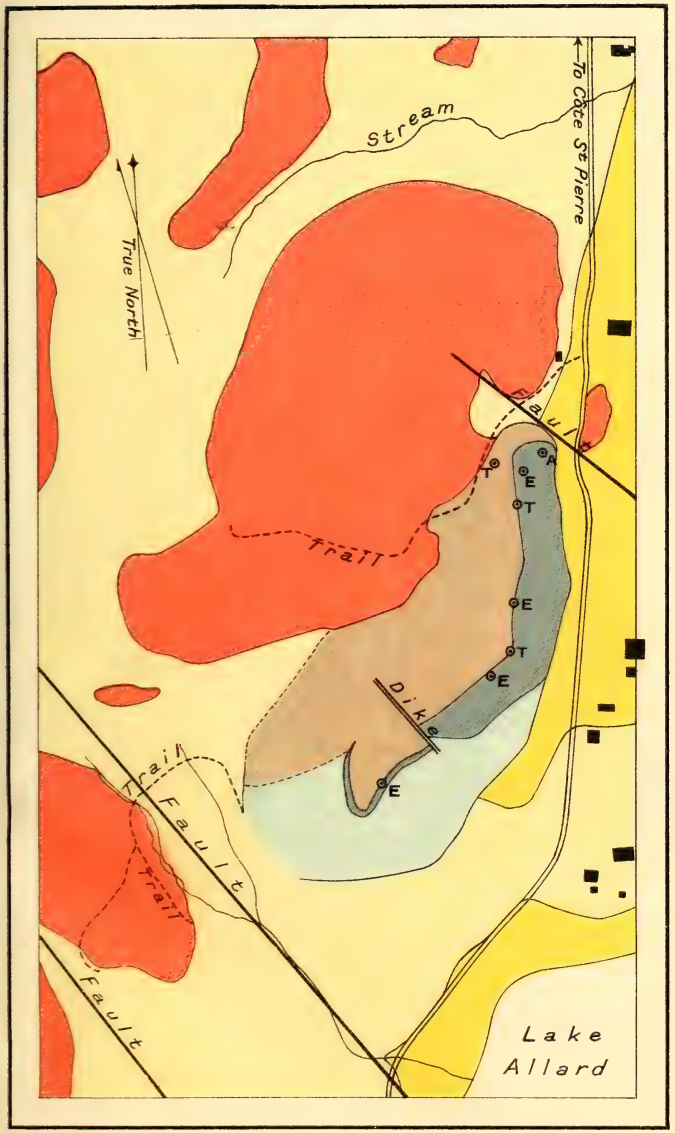
THE EOZOON OCCURRENCE AT CÔTE ST. PIERRE.

Geological Relationships.

In this classic locality the Pre-Cambrian formations are obscured to an unfortunate degree by Leda clay and sand. Two Pre-Cambrian rock-types are present : impure Grenville limestone, and a younger intrusive of plutonic habit, that ranges in composition from biotite-hypersthene-gabbro to quartz-syenite. The contact between the two is characterized by certain important contact metamorphic phenomena. Several N.W.—S.E. faults find topographic expression in the small area included by the map. It would appear from these that either the limestone block had



Côte St. Pierre. Eozoon locality to left of picture.



Geological Survey, Canada

Côte St Pierre

Feet
100 0 400 800
Metres
50 0 200

Legend

Post-Glacial
- Sand
- Clay

Pre-Cambrian
- Diorite
- Serpentine limestone
- Diopside rock
- Grenville limestone

- ⊙A Asbestos
- ⊙T Tremolite
- ⊙E Eozoon

been pushed relatively farther to the north-west than the neighbouring rock-masses, or that these have been moved farther to the south-east than the limestone block.

The Eozoon occurrence can be understood best by first becoming acquainted with the igneous rock, and afterwards working across the contact zone, in which the Eozoon occurs, to the normal limestone. The main part of the intrusive mass is a biotite-hypersthene-gabbro varying in parts of the map area to quartz-diorite or quartz-syenite. So far as the intrusion has been studied there appears to be an increasing basicity towards its margin, probably due to differentiation of the intruded magma.

A quartz-syenite phase of the intrusive from the south-west corner of the map area consists essentially of hypidiomorphic hornblende, orthoclase and biotite, with smaller quantities of augite, micro-perthite, plagioclase, quartz, apatite and ilmenite. A small amount of quartz and feldspar are micrographically intergrown. The hornblende is green and strongly pleochroic : c-very dark green, b-very dark green, a-greenish yellow. Occasionally it encloses kernels of non-pleochroic augite, from which it appears to have been derived during the cooling of the magma. This phenomenon is illustrated by all phases of the intrusive in this locality.

The rock from the north-west corner of the area is composed of the same minerals, but there is no micrographic intergrowth, and plagioclase is relatively more inportant than orthoclase. In a diorite phase from the centre of the map area orthoclase becomes subordinate in amount, and quartz is only sparingly represented. The hornblende is sometimes micro-poikilitically intergrown with feldspar, and the latter mineral is also filled with minute needle-shaped inclusions.

Other specimens, more especially those from near the contact with the limestone, are gabbros. Pyroxenes are more important than hornblende, though still showing incipient reaction rims of that mineral. Both monoclinic and rhombic pyroxenes are present. The rhombic variety has the pleochroism of hypersthene and sometimes occurs as kernels enclosed by augite. Apatite, titanite and magnetite are more concentrated than in those phases which lie further away from the contact.

The actual contact of the gabbro and the altered limestone can be seen at one or two points near the trail

which runs from the small boiling-shed at the road-side through the maple bush. For 300 feet (91·5 m.) away from the contact is a light-greenish, almost white rock of coarsely granular texture, which consists almost wholly of diopside, though scapolite, titanite and tremolite are also present. A variety composed solely of tremolite is found more especially at the edge of the diopside rock, away from the igneous intrusion. Between the diopside rock and the normal limestone is a zone of serpentine varying in width from 10 to 100 feet (3 to 30·5 m.). For the most part the serpentine and calcite show the indefinite arrangement of ordinary ophicalcites, but at one or two points they show that arrangement which has given rise to the name Eozoon canadense. It is important in the latter case to note that the width of the serpentine bands varies greatly, some specimens showing 10 bands per inch (4 per cm.), while in others the bands are two inches (4·8 cm.) wide. The normal limestone is found only at the southern edge of the exposure and has the usual impure character, mica flakes being the most conspicuous mineral associated with the coarsely granular carbonates.

Nature of Eozoon Canadense.

Sections of Eozoon have been so often described that it will suffice here to draw attention to the structure of the serpentine. Very often it possesses a "mesh-structure," less often a "knitted," and rarely a "lattice-structure." The two former types are derived from diopside and the latter from tremolite. The meagre development of cleavage in longitudinal sections of diopside is noticeable in thin sections of the diopside rock. For this reason, and also because basal sections would naturally be in a minority in any rock slice "mesh-structure" is more common than "knitted-structure." Mesh-structure is usually regarded as characteristic of serpentine formed from olivine, but in the present case no connexion with any mineral of the olivine family can be established; on the contrary, the serpentine can be found still retaining kernels of diopside.

Osann concluded that this mineral association was the product of thermal metamorphic action on the Grenville limestone [**2**]. The cartographical and further microscopical study made by the present writer support this

conclusion. Transfusion of silica in solution, and titaniferous and chlorine-bearing vapours or solutions would provide the conditions necessary for the formation of the minerals found in the field. A later circulation of heated juvenile waters appears to have exercised a selective action upon the outer edge of the altered zone, causing serpentinization of diopside and tremolite, and even at one point forming a vein of asbestos from the serpentine. But while the mineral assemblage found in this locality may be thus explained, no process for the formation of those detailed and beautiful structures which led to the Eozoon controversy is known.

Historical Outline.

Though this is not the locality where Eozoon was first discovered, it has furnished some of the best specimens and it was in specimens obtained here that Sir J. W. Dawson found the structure which he called *Eozoon canadense*. It was first noticed in a specimen from Burgess, Ontario, and was found in place in 1858 at Grand Calumet, Quebec, by Mr. McMullen, of the Geological Survey of Canada. Collections from Côte St. Pierre were made between the years 1863 and 1866 by Mr. J. Lowe, of the Survey. Extensive collections were made by Sir J. W. Dawson and Mr. T. C. Weston, between 1873 and 1877. A great many of these examples were sectioned, carefully examined and faithfully described by Sir J. W. Dawson and Dr. W. B. Carpenter in their final stand in support of the organic origin of the structure, which had been questioned, in some cases by equally careful observers. The importance of the structure from a palæontological point of view, and its recognition in other countries, led to a re-examination of this area by Mr. A. Osann in 1899, under the auspices of the Geological Survey of Canada. In his report he described the igneous rock and its metamorphic effects on the limestone.

ANNOTATED GUIDE—Continued.

Impure Grenville limestone is exposed in the left bank of Lievre river at Buckingham. Close to the water's edge it contains thin bands of apparently igneous material, which have been

Miles and Kilometres.

intensely folded or stretched out, so that a once continuous band of rock has been broken into a string of small isolated blocks. A small inclusion of this character, from the Dominion mine, was examined and proved to be a scapolite gabbro.

130 m. 208 km. For the first mile (1·6 km.) after turning north at McFall's Corners, exposures are not common near the road. The main outcrops are of Ottawa gneiss of igneous origin, chiefly biotite syenites and diorites, with smaller amounts of gneisses similar to the hypersthene-granites at the Emerald mine.

132 m. 211·5 km. Just before reaching the cheese factory, shells (*Astarte laurentiana*, Lyell) are to be seen in the Leda clay on the left hand side of the road. A mass of granulite with included small bands of limestone is exposed opposite the cheese factory.

132·4 m. 212 km. The rise in the road farther north is caused by a bank of sand and coarse gravel, which is exposed just beyond the summit of the rise and shows a stratification parallel to the outline of the hill. This was doubtless a sand-bank in the Saxicava sea close to some local source of fluvio-glacial material.

135·1 m. 216 km. Immediately north of the school-house a small hill of Grenville limestone is visible on the left hand. From here Leda clay continues for two-thirds of a mile (1·1 km.), and for half a mile (·8 km.) along the side road to the mine. The road skirts a hill composed of dioritic gneiss and impure limestone bands cut by pegmatite dykes. Rising over this hill the approach to the Walker mine is covered with Leda clay; while at no great distance on either hand are cliffs and rounded hillocks of dioritic Ottawa gneiss.

THE GRAPHITE DEPOSITS AT THE WALKER MINE.

General Geology of the Locality.

Grenville limestone, the oldest Pre-Cambrian rock in this locality, occurs on the hill above the smaller mill-pond and to the south of the larger pond. Also, in the northwestern part of the area it is represented by a broader band which extends in a direction somewhat east of north. This limestone band is flanked on either side by Ottawa gneiss, the most important member of which is a quartz-rich variety, very similar in appearance to the hypersthene-granites of the Emerald mine. Small graphite bodies are occasionally seen in this gneiss, more especially on joint faces Pegmatitic phases are developed in the extreme north-western corner of the area. Small amounts of para-gneisses may be included in this igneous complex, but as yet none have been definitely recognised.

The larger part of the map area is occupied by more basic varieties of Ottawa gneiss than those just described. They consist of gabbros and diorites with pyroxenite, amphibolite, anorthosite, and hypersthene-gabbro basic variations. Scapolite is of common occurrence in these basic gneisses, which appear to be younger than those described above. In the northern part of the map area a younger gabbro has been separated from the other basic gneisses, but otherwise the relative ages of the intrusions constituting the basic part of the complex remain unknown.

At a distinctly later period in Pre-Cambrian time, the Grenville limestone and Ottawa gneiss were invaded by pegmatite, diorite and gabbro dykes, which probably represent more than one magmatic intrusion. The graphite ore bodies are always found in close association with these dykes. One of the pegmatite dykes has graphite distributed throughout its mass in great abundance.

Geological Relationships of the Graphite Deposits.

The main pit is situated at the foot of a cliff, which, from top to bottom, consists of biotite-diorite-gneiss, a horizontal dyke or sheet of biotite-diorite from 6 to 20 feet (1·8 to 6·1 m.) in thickness and a much altered limestone. Immediately to the south the limestone is also

in contact with a biotite-rich gneiss different in appearance from the biotite gneiss at the top of the cliff. The graphite ore-body is situated underneath the diorite sheet and at the contact of the limestone with the gneiss. The graphite is in the limestone rather than in the gneiss,



Columnar graphite and altered Grenville limestone, Walker mine [Nelly's pits].

though some of the latter is impregnated with graphite. The ore-shoot is about 30 feet (9·1 m.) wide and the same in length. It strikes N.S. and pitches 57° to the south, and has been worked by means of a tunnel, now filled with water. The ore-body and the igneous sheet above it can be likened to the stalk and head of a mushroom, an analogy

which brings out the fact that the ore-body does not lie close to the contact of the intrusive and the limestone.

The altered limestone near the ore-body contains in addition to calcite a colourless monoclinic pyroxene, probably diopside; scapolite, which sometimes shows strain-shadows, and, as might be anticipated, has a birefringence near that of meionite; microcline and a little plagioclase, both strained and often broken into small grains; and a considerable quantity of titanite characterized by strong reddish pleochroism. Graphite is associated with calcite and feldspar, more especially with the latter mineral and is for the most part of later formation than these minerals, though in some instances it preceded the feldspar. Pyrite was formed later than the graphite. The rock is banded in structure, some bands being richer in calcite than others. The graphite occurs mostly in the feldspathic bands. The whole rock gives evidence of having been subjected to pressure, subsequent to its alteration, the scapolite showing this more clearly than any other mineral. A thin section of the ore consists chiefly of graphite together with some titanite, a later formed scapolite and still later pyrite which sometimes has grown along the cleavage cracks of the scapolite. The relation of the graphite to the minerals which accompany it is not shown, but the presence of these minerals indicates that the ore is an impregnated altered limestone, a conclusion which is also reached by studying the field relations.

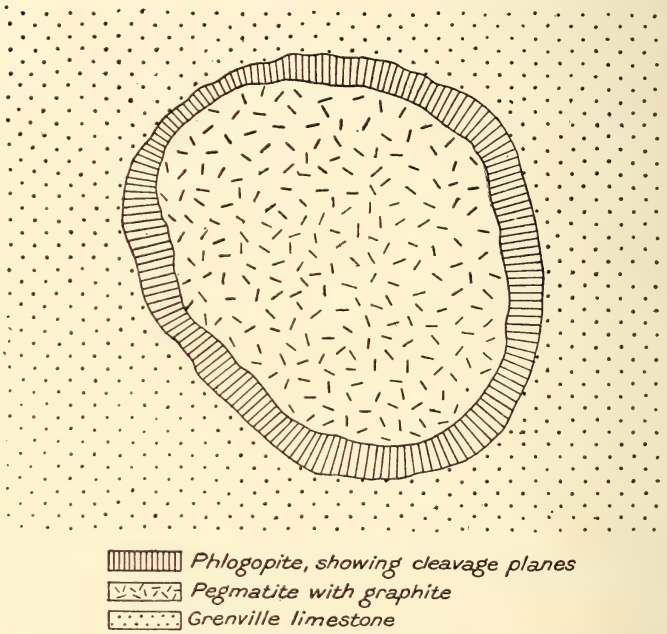
At an opening 500 feet (152 m.) north of the main pit graphite forms bodies one foot in width on both sides of a pegmatite dyke. The flakes of graphite are parallel to the walls of the dyke, and are regarded as impregnations of the country rock. The ore here and at the main pit belongs to the type known as "disseminated ore".

At the now overgrown openings at the extreme south-western corner of the map area (Nelly group of Osann) [**2**], the ore occurs as "vein or columnar graphite". So far as can be seen from the poor exposures, the veins containing graphite are developed near the contact of a gabbro with Grenville limestone. A few specimens of the columnar graphite may be obtained from the dumps, which also furnish apatite, titanite, scapolite and pyroxene, the associated minerals of the graphite veins. Titanite crystals up to the size of a hazel nut can be found and also pyroxene combs like those of the apatite and mica veins. The graphite,

where found in place, has its fibres at right angles to the walls of the vein. The veins range up to four inches (·1 m.) in width.

Osann describes a gabbro from this locality [2], which has many features in common with the gneiss capping the hill at the main pit. This rock is coloured as gabbro on the map.

At a point above the smaller mill-pond, Grenville limestone is intruded by a small patch of pegmatite, which



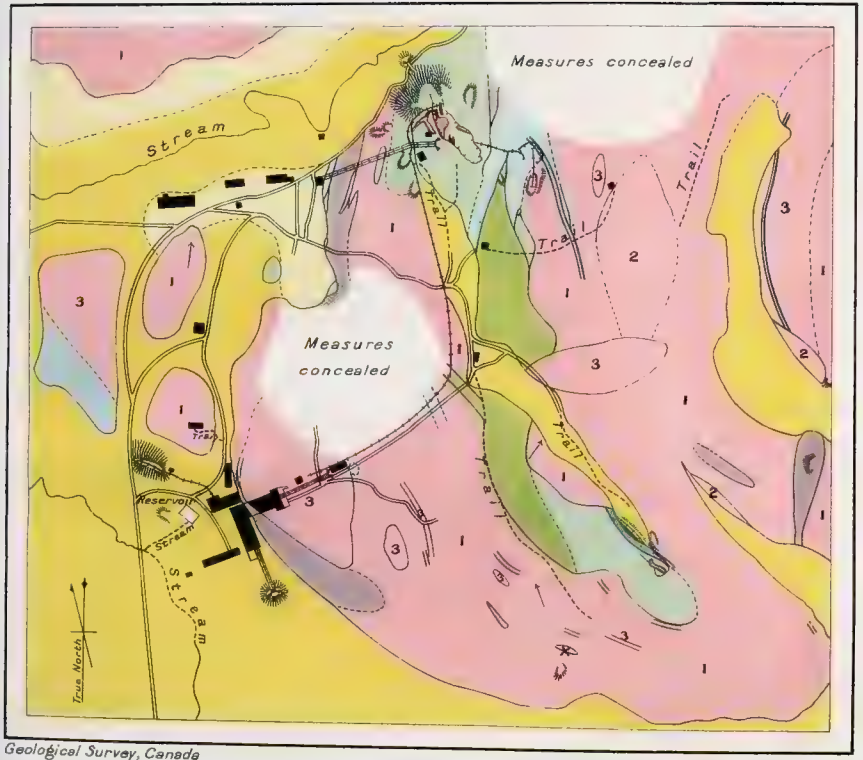
Radially arranged phlogopite rim between graphitic pegmatite and Grenville limestone, Walker mine.

carries graphite within its mass, and is separated from the limestone by a rim of phlogopite in which the flakes of the mica are set at right angles to the margin of the pegmatite block.

Graphite was first shipped from this locality in the seventies, but at that time only columnar graphite was



Ge



Legend

Post-Glacial

- Saxicava sand
- Leda clay

Pre-Cambrian

- "Blue quartz" veins
- Anorthosite
- Gabbro
- Pegmatite
- I-3 Ottawa gneiss
 - 3. Diorite, etc.,
 - 2. Quartz-pyroxene gneiss
 - 1. Biotite-syenite gneiss
- Grenville limestone

- Graphite ore-body

Geological Survey, Canada

Dominion Mine, Buckingham Township, Quebec.

Feet: 100 0 200 400 600 800 1000

Metres: 100 80 60 40 20 0 200



marketed. The main pit was worked from time to time between 1890 and 1896. The ore was first roasted in kilns and then treated with water to make it more readily crushable, and the graphite was separated by a wet process.

ANNOTATED GUIDE—(Continued.

Miles and Kilometres.

142·8 m. 228 km. The road from Buckingham is followed back to McFall's Corners, and from there a westward direction is taken. The first rock exposed in the road is impure Grenville limestone immediately followed by a rock so rich in garnets that, in the hand specimen this mineral is the most conspicuous constituent. This rock has the character of an altered norite. It is followed by a more normal gabbro, similar in some of its aspects to the diorite which caps the hill above the main pit at the Walker mine. This gabbro is cut by two broad, parallel dykes to which the convenient field name, "blue quartz veins," has been applied. The first one has a width of 200 feet (67 m.), and the second a width of 60 feet (18·2 m.). From this hill to the Dominion mine black and rusty weathering gneisses alternate with Grenville limestone.

THE GRAPHITE DEPOSITS AT THE DOMINION MINE.

In the vicinity of the Dominion mine, Grenville limestone and a small amount of associated sillimanite-gneiss have been intruded by mica-syenite-gneisses. These, in their turn, have been intruded by quartz-pyroxene-gneisses comparable to the hypersthene-granite-gneisses of the Emerald mine, and by diorites, pegmatites and gabbros. The age relations of these various intrusives are not always clear; the nearest approach to a chronological order, at present possible, is shown in the legend of the map. Many small pegmatite and diorite dykes occur in the gneisses of the area.

The rocks that command attention most are the varieties of gabbros with which the graphite ore-bodies are associated. These have intruded the Grenville limestone and older gneisses and have caught up masses of limestone

within themselves. Graphite has been deposited either at the junction of the igneous rock with its country rock, or in the included masses of limestone, or in the body of the igneous rock itself. Hence, the ore may be impregnated gneiss, impregnated limestone, or impregnated gabbro or pyroxenite. It occurs in the form known as "disseminated" graphite, but not as "vein or columnar" graphite.

The occurrence at the main pit is the most instructive. Here the ore occurs in a shoot of roughly lenticular cross-section, which sends offshoots or stringers into the surrounding rock. The whole ore-body occurs within a mass of gabbro, in which there are also "horses" of limestones, near which the graphite is more concentrated than elsewhere.

The gabbro appears to be a normal type, except that it sometimes contains small quantities of quartz and of graphite.

Both gabbro and ore are cut by "blue quartz veins," which seem to be the latest products of the gabbro intrusion. These veins are composed largely of quartz filled with minute inclusions, a variety of hornblende showing grass-green, drab and light yellow pleochroic tints being the only other mineral of importance. A little pyrite and graphite are the only other minerals present. The graphite is in part earlier than quartz, and in part later.

A sample of ore from this pit proved to be a pyroxenite composed mainly of grey augite. Brown, strongly pleochroic biotite is common; orthoclase, a smaller amount of plagioclase, titanite with strong reddish pleochroism, interstitial quartz, and a minute quantity of brown hornblende are also present. Pyrite is older than the pyroxene, but graphite is one of the latest minerals to be formed. It occurs along the cleavage cracks of biotite, and at some points can be seen penetrating two adjacent grains of feldspar or of quartz. The presence of quartz in a pyroxenite is another interesting feature.

Other minerals associated with the graphite are apatite, in masses up to the size of a hen's egg, pyrite, sometimes as veins of honeycomb or drusy nature cutting the ore, and molybdenite, of which a few flakes have been recognized.

Some examples of the calcareous ore, from their appearance in hand-specimen, indicate that the calcite, though probably derived from the limestone, was dissolved

by the waters accompanying the igneous intrusion and re-deposited from solution, along with the graphite. This calcite has a distinctly different appearance from that of the ordinary Grenville limestone.

About 200 feet (61 m.) southeast of the main pit is another opening, in which one of the blue "quartz veins" is seen cutting Grenville limestone. A dense aggregate of graphite flakes reaching a thickness of one foot was found on both sides of the vein.

At the swamp pit, not now exposed, highly altered limestone is in contact with a biotite-gabbro, which is cut by "blue quartz veins." The ore, which attained two or three feet (·6 to ·9 m.) in thickness, was entirely within the gabbro.

An interesting section is to be seen at the opening in the south face of the Pre-Cambrian area. At this point, where the rocks have a dip of 60° to the north, there is a band of ore one foot (·3 m.) thick at the contact between sillimanite-garnet-gneiss and an overlying limestone. Near the ore the limestone is dark blue in colour with lighter yellowish patches in it up to the size of a hazel-nut. Above this the limestone is coarsely crystalline. The cause of this colouration is not known.

The Dominion mine was opened up in 1910 and the mill was erected in the latter part of that year. Work was continued until the latter part of the summer of 1912. The ore is roasted in kilns at the top of the hill so that it may be more readily crushed, and passes by gravity through a series of crushers. On reaching the mill the graphite flakes are flattened and separated by a dry process, the fine rock powder passing through rotary screens which do not allow the graphite to pass.

ANNOTATED GUIDE (continued).

Miles and Kilometres.

154·6 m. 247·5 km. Immediately west of Buckingham Junction station the Lievre river falls over the Pre-Cambrian margin just before joining the Ottawa river. Continuing westward, the railway follows the Pre-Cambrian margin, which is more masked by the blanket of post-Glacial deposits than it is to the east of Buckingham.

158·4 m. 253·5 km. **Angers**—Alt. 183 ft. (55·7 m.).

Miles and Kilometres.

164·3 m. 263 km. **East Templeton**—Alt. 159 ft. (48·4 m.). Ottawa gneiss of a granitic character is much cut up here by pegmatite and quartz veins, which are easily seen from the railway. A short distance farther west the top of the Potsdam scarp can be seen on the left hand, between the railway and the Ottawa river.

The Gatineau river is crossed about two miles above its junction with the Ottawa.

173·1 m. 276·5 km. **Hull**—Alt. 189 ft. (57·5 m.). Before reaching Hull, quarries in the Trenton limestone are passed, which admirably display the character of this formation in the vicinity of Ottawa. The other members of the Ordovician are not exposed along the railway.

175 m. 280 km. **Ottawa** (Broad St.)—Alt. 175 ft. (53.3 m.).

176.9 m. 283 km. **Hull**—Alt. 189 ft. (57.5 m.) The railroad crosses the Ottawa river a half mile (.8 km.) above Chaudière falls and runs north along the west bank of the Gatineau river which debouches into the Ottawa at Hull. Chaudière falls and the gorge below are in Trenton limestone, which underlies the north and west parts of the city of Ottawa. To the east and south-east, Utica shale, having an estimated thickness of 400 feet (112 m.), conformably overlies the Trenton. It has yielded *Triarthrus becki*, Green, *Isoelus canadensis*, *Leptograptus flaccidus*, Hall, *Orthograptus quadrimucronatus*, Hall, and many other Utica fossils. A half mile (.8 km.) west of the railway bridge across the Ottawa, the Trenton series is terminated by the Hull and Gloucester fault which, starting in the vicinity of Rigaud, runs west toward Ottawa for a distance of 65 miles (104 km.), then curving toward the north crosses the Ottawa river at this point and Gatineau river about Ironsides village. Immediately west of the fault near the Ottawa river the Trenton is succeeded by Black river limestone, with the Chazy series still farther west. All the Palæozoic sediments in the vicinity of Ottawa are nearly horizontal, except near faults

Miles and Kilometres.

where the dip rises to 75°. Excellent exposures of flat-lying Trenton limestone are to be seen on both sides of the railroad in the vicinity of Hull. From these limestones, which have a total thickness of about 600 feet (183 m.), more than 50 species of fossils have been recorded, including *Plectambonites sericeus*, Sowerby, *Pachydictya acuta*, Dekay, *Zygospira recurvirostris*, Hall, and others.

The faulted northern boundary of the Trenton, where it abuts against beds of the Chazy series, is not exposed, being covered by a heavy deposit of Leda clay. This conjunction of clay and limestone, both of a high degree of purity, is as advantageous for the production of cement as any in the country. The large plant of the Canada Cement Co. testifies to these propitious geological conditions. Extensive quarries for building stone, lime and cement have also been opened in the Trenton limestone.

177.6 m. 284 km. **Maniwaki Junction**—

180 m. 290 km. **Ironsides**—Alt. 182 ft. (55.3 m.). The Chazy, Calciferous and Potsdam formations appear in that order toward the north, the Potsdam resting unconformably on the Pre-Cambrian. All of these formations and their faulted western contact with the Pre-Cambrian, are covered along the Gatineau Valley railway by Leda clay which is in turn covered by Saxicava sand, though in places this has been subsequently removed, as for example between Maniwaki Junction and Chelsea.

184.1 m. 295 km. **Chelsea**—Alt. 365 ft. (110.6 m.). Immediately north of Chelsea station the first exposures of Pre-Cambrian are found. On the east side of the track is a richly garnetiferous gneiss with vertical banding, which is cut by pegmatite veins.

185.1 m. 296 km. Grenville limestone intruded by binary granite and mica diorite is exposed in a cutting at this point. The limestone is in highly inclined or contorted bands of various thicknesses. Further north the limestone is followed by more exposures of binary granite.

Miles and Kilometres.

186.6 m. 298 km. **Tenaga**—Grenville limestone is exposed in the bed of the small creek to the west of the track. The Gatineau river has a large and strong whirlpool at this point.

The chute below Kirk Ferry owes its existence to a band of Grenville limestone, followed on the upstream side by a band of syenitic and granitic gneiss. The strike of the contact is approximately at right angles to the river, and the different resistance of the two rocks to erosive forces has given rise to the fall. The limestone is exposed in a cutting just below the fall, where associated intrusions of binary granite and gabbro, the latter with typical veins of the mica-bearing type, can also be seen. A two foot (·6 m.) vein of mountain cork in the same cutting is worthy of passing mention. Immediately north of the cutting, vertically disposed gneissic banding is excellently displayed in the face of a small cliff to the right of the railroad track.

187.9 m. 300 km. **Kirk Ferry**—Alt. 294 ft. (89.9 m.). After crossing the river and climbing up a bank of Leda clay the road runs along the edge of a hill of granite-gneiss which is typical for the district, though in some places, for example the north hill of the Nellis mine, gneissic banding is more strongly developed.

Tourmaline pegmatites are a feature of the district, and several of them, cutting the granite-gneiss, can be seen from the road.

190.7 m. 305 km. Near the bend in the road can be seen an exposure of very impure limestone. In addition to carbonates this rock contains pyroxene, plagioclase, microcline, light brown mica, titanite and pyrite. On the roadside approaching Blackburn creek, Leda clay is exposed. This is one of the few points in the district where the lamination can be seen. Granitic gneiss is exposed just east of Blackburn creek, and the exposures to the south have similar rocks much injected by pegmatitic dykes and veins.

Miles and Kilometres.

192 m. 307 km. An exposure of Grenville limestone at this point is followed by granite-gneiss, which is intruded by pegmatite, and, still later, by two dykes of diorite. South of the post office at 194.7 m. 312 km Cantley, a series of black and rusty-weathering gneisses make a slight rise to the west of the road. Turning in at the road to the mine a small outcrop of limestone is passed and the north hill of the Nellis mine is reached.

THE MICA DEPOSITS AT THE NELLIS MINE.

Geological Relationships of the Deposits.

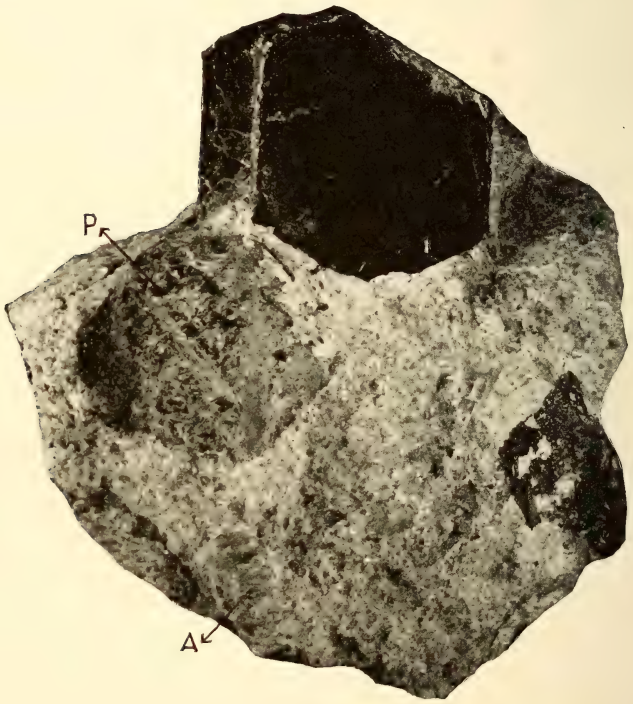
The veins worked at the Nellis mine occur on two "hills" separated from each other by a clay filled hollow, in which a small post-glacial creek has cut a deep valley.

On the north hill, which is shown on the map, the Ottawa gneiss is intruded by a small stock of scapolite gabbro, and by an elliptical intrusion of gabbro-pegmatite. Mica-bearing veins cut all of these rocks. The Ottawa gneiss is an augite gneiss similar to the granite-gneiss seen along the road, except that the gneissic banding is more strongly developed. It is cut, without regard to the direction of the gneissic banding, by mica-bearing veins. The greater part of the gabbro contains an important amount of scapolite in addition to augite and minor amounts of plagioclase, phlogopite, sphene, apatite and sulphides. A sugary anorthosite phase occurs at two points. Another variation from the average type occurs at the east central part of the stock. It is a black amphibolite, in some specimens of which epidote can be seen in the hand-specimen, though hornblende is the sole constituent of importance. The gabbro-pegmatite is composed of feldspar with a little quartz. The feldspar is chiefly microperthite with some microcline and plagioclase.

Character of the Veins.

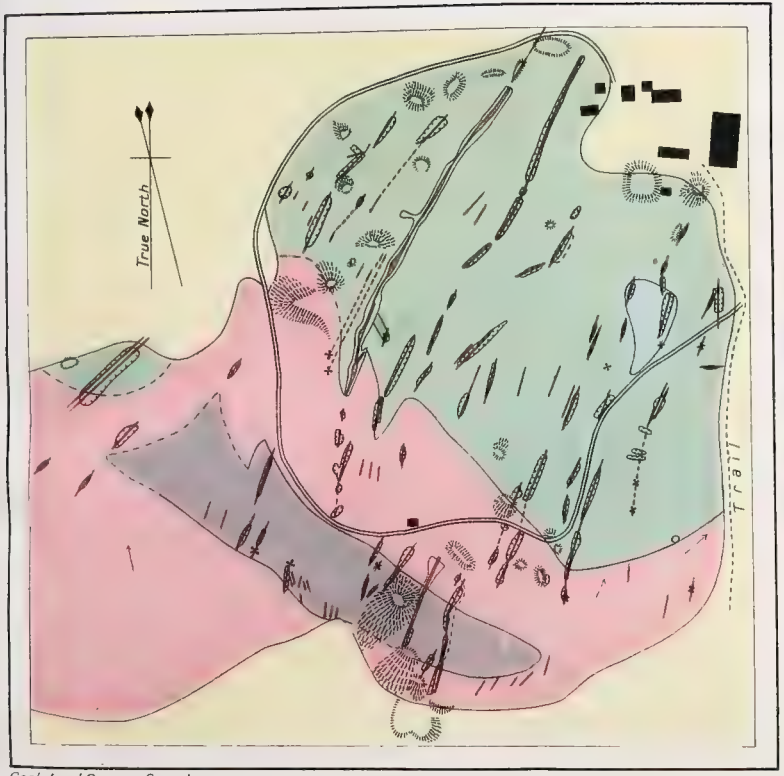
Mica-bearing veins occur more abundantly in the gabbro area than in the gneiss or gabbro-pegmatite. They form a parallel series, striking N. 68° E. (mag.) at the northern end of the hill, and swinging round to N. 23° E. (mag.),

at the southern end. Only one vein runs at right angles to this general direction. The veins are about 15 feet (4·5 m.) apart on the average, and dip to the east from 37° to 87°. The vein walls are rectilinear in the gneiss and gabbro-pegmatite, but in the gabbro they are more inclined to irregularity. A banded vein structure is general, the typical vein having a comb of black or dark pyroxene crystals growing at right angles to the vein-walls



Mica [phlogopite] with pyroxene [P], apatite [A] and calcite. Vein matter,

and possessing terminal faces on the ends which project into the vein. Next to each pyroxene layer is a band of mica crystals, with their cleavage planes more often parallel to the vein-walls than at right angles. Each mica layer is succeeded by one of green apatite, and the centre is



Legend

- Post-Glacial
 - Saxicava sand
- Pre-Cambrian
 - Gabbro-pegmatite
 - Anorthosite
 - Amphibolite
 - Gabbro (in part scapolite gabbro)
 - Ottawa gneiss granite
 - Mica-bearing veins

Geological Survey, Canada

Nellis Mine, Cantley, Quebec

Feet
100 0 200 400

Metres
50 0 100



filled with pink or white calcite. Individual veins may lack the apatite, or the calcite, but more often the two occur together in the centre, perfectly formed apatite crystals being embedded in the calcite. Sometimes perfect crystals of phlogopite are also found embedded in the calcite. The calcite gives a strong strontium flame reaction. Quartz, fluorite, tourmaline and actinolite are of less frequent occurrence.

Some of the veins follow lines of faulting. Sometimes also they are displaced laterally for a few feet, but whether this is due to subsequent faulting or to an original discontinuity of the fractures cannot be determined under present conditions. Changes in thickness of the veins are more common in the gabbro than in the other types of country rock. Bulging and narrowing of the vein is especially well seen along the main lead. The same variation is shown in depth, a vein which may be only one foot (·3 m.) in width at the surface widening to 10 to 15 feet (3 to 4·5 m.) underground. An example of this can be seen at the south face of the hill. This characteristic is recognized in prospecting, and further work on apparently lean veins at the surface has been rewarded frequently by the discovery underground of wider veins carrying important bodies of mica. At present the veins are being worked for mica, the apatite being taken out and stocked on dumps.

The south hill is occupied by a mass of binary granite intruded by a dyke-like mass of scapolite gabbro similiar to that occurring at the north hill. The veins are found more especially along the eastern face of the hill near the gabbro dyke, and strike parallel to those of the north hill. The veins are exactly similiar to those seen on the north hill, except that calcite is almost lacking, and the apatite is usually of a reddish colour rarely seen on the north hill.

ANNOTATED GUIDE (continued.)

Returning to Kirk Ferry, granite-gneiss and intrusive pegmatites are seen west of Langside farm, and, at the rise in the road, a mica vein is exposed. Opposite Wilson's farm the gneiss is cut by an aplite dyke, composed of plagioclase and quartz, with a little magnetite.

At the bend of the road just beyond, a white Pre-Cambrian quartzite is exposed on the west side of the

road. This rock has been thoroughly cemented, quartz being deposited around, and in crystalline continuity with the original grains of sand.

Opposite Farmer's cottage the granitic gneiss of the district is intruded by tourmaline pegmatite, rich in tourmaline. The feldspar of the rock is microcline, and in thin section the tourmaline is brown and shows zones of colouring. North of the road at this point, and distant about 200 yards (183 m.) from it, is a gneiss very rich in pink garnet.

The extensive intrusion of pegmatite veins to which the Pre-Cambrian gneisses have been subjected is illustrated near the ferry by a few patches of granite-gneiss which outcrop through the Leda clay.

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EXCURSION A 10.

PLEISTOCENE—MONTREAL, COVEY HILL AND OTTAWA.

By J. W. Goldthwait, W. A. Johnston and Joseph Keele.

CONTENTS.

PAGE

Introduction.
by J. W. Goldthwait..... 118

The upper marine limit at Montreal.
by J. W. Goldthwait..... 119

The upper marine limit at Covey Hill and vicinity.
by J. W. Goldthwait..... 122

The superficial deposits near Ottawa.
by Joseph Keele and W. A. Johnston..... 126

Geology of the superficial deposits..... 126

Glacial deposits..... 126

Marine deposits..... 128

Local descriptions..... 130

Drainage features..... 133

Itinerary of excursion..... 134

Alternative excursion..... 134

Bibliography..... 134

INTRODUCTION.

BY

J. W. GOLDTHWAIT.

The purpose of this excursion is to study certain records of submergence of the St. Lawrence valley by the sea at the close of the Glacial period. The evidences of this submergence are both geologic and physiographic. Clays containing marine shells of an arctic or sub-arctic fauna will be seen at altitudes a few hundred feet above the present level. Wave-built beaches, marking the former stand of the sea against the hillsides will be visited and critically examined at various altitudes up to 570 feet. Particular attention will be given to the determination of the upper limit of submergence.

Of the three localities visited, Montreal lies on an ancient island of the Pleistocene sea, near the middle of what was then the great St. Lawrence embayment. Covey hill lies on the south shore of this Pleistocene estuary in a critical position with reference to earlier, higher water levels; for while the ice sheet still rested against its northern slope great pro-glacial lakes occupied the valleys of Lake Ontario and Lake Champlain. Ottawa lies far up one of the long arms of the Pleistocene embayment, on the north side. Here, as well as in the other localities, the relation of the marine sediments to the earlier, ice-laid deposits will be seen.

On the outline map which accompanies this guide, the south shore of the ancient Champlain Sea is shown from the City of Quebec to Lake Champlain and the Adirondacks; also the altitudes of the highest marine beach, in feet above sea level, at several localities in this district.

THE UPPER MARINE LIMIT AT MONTREAL.

BY

J. W. GOLDTHWAIT.

The question of the upper limit of marine submergence at Montreal has long been a disputed one. Unusual interest is attached to the locality because of contradictory opinions of such experts as Sir Charles Lyell, Sir William Dawson, and Baron Gerard deGeer.

Mount Royal is one of several volcanic mountains which rise above the St. Lawrence lowland. The St. Lawrence lowland, which surrounds the mountain on every side, is a plain of subaerial denudation base-leveled during the Tertiary, covered by the North American ice sheet during the Glacial period, and upon its withdrawal deeply submerged by the sea. Marine sediments extend far and wide over it. Exposed at many places are shells of marine species similar to those now living in polar regions. Since the withdrawal of the ice the region has emerged from the sea, in this locality to a height of nearly 600 feet (182 m.). Although the exposed position of the mountain which, during the great submergence, was an island in the sea, was highly favorable for wave work, the side slopes of the mountain were in most places too steep for such action, particularly at higher levels.

The discovery of marine shells on the grounds of McGill University and at higher places on the mountain long ago raised the question as to how deeply the mountain had been submerged. Sir Charles Lyell reported a beach which contained Saxicava shells at 470 feet (143·25 m.) on the south-west side of the mountain above Côte des Neiges village. His description of this locality given in his "Travels in North America" makes it seem probable that the shell-bearing deposit lies beneath boulder clay rather than above it, and hence is to be interpreted as an inter-glacial marine deposit instead of a deposit formed during the last submergence. In any case it is now known that the recent submergence reached to higher altitudes than this. Sir William Dawson, an ardent follower of Lyell, accepted in full his "drift theory" which accounted for all

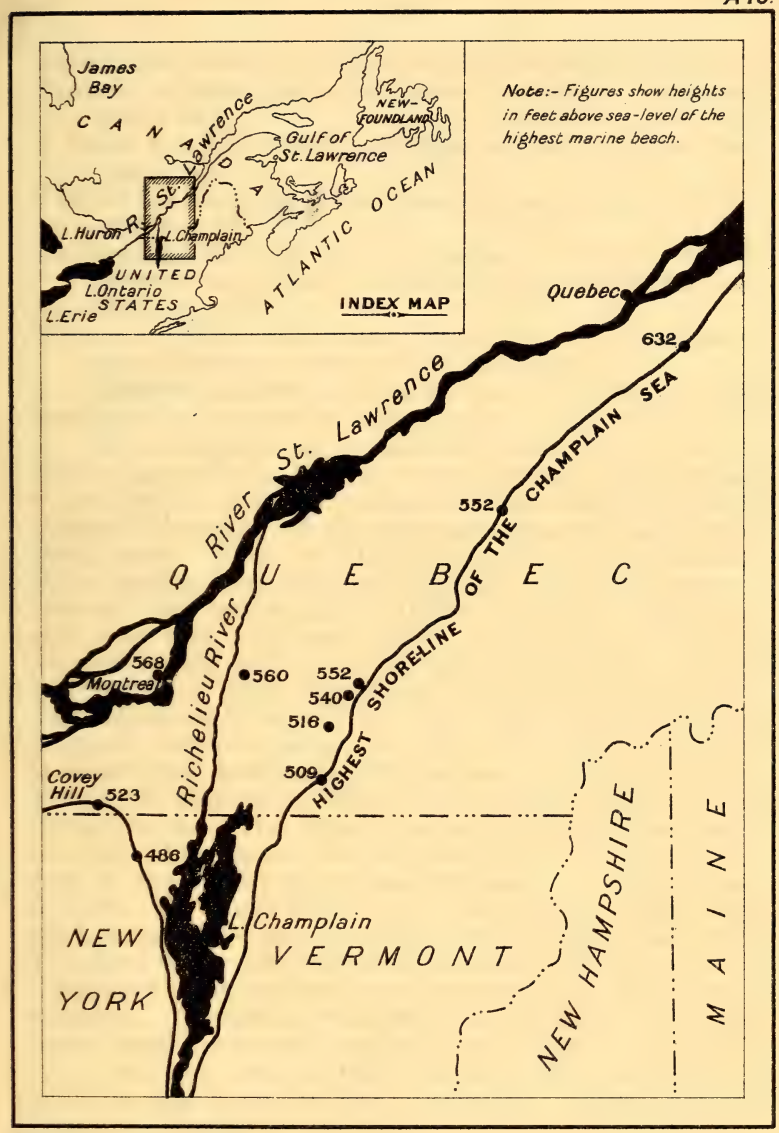
boulder clay by the grounding of icebergs and pack ice in shallow waters over a temporarily submerged coast. From the occurrence of erratic Laurentian boulders on the summit of Mount Royal he argued, as late as 1893, that the entire mountain had been submerged. This put the minimum limit of submergence above 700 feet (213·3 m.), [**3**, p. 63]. The highest shell locality reported by Dawson was 560 feet (170 m.) above the sea. In 1892 Baron deGeer, accompanied by Professor F. D. Adams, selected as the highest level of submergence a bench and cliff on the northwest side of the mountain behind Mount Royal cemetery. The altitude of this bench was given as about 625 feet (190·5 m.) [**2**, pp 454-457]. DeGeer's determination has since been very generally accepted.

During the last four years detailed studies for the Geological Survey of the records of marine submergence in the St. Lawrence valley have thrown new light upon features which may be expected on Mount Royal. The following points are important:

(1) Transported boulders are of no value as an evidence of marine submergence. While they are plentifully scattered over the area which is known to have been submerged, they also occur at all altitudes above the level of submergence where they have been left by the continental of ice sheet.

(2) In spite of statements to the contrary, wave cut benches and sea cliffs are almost unknown along the upper line of marine submergence in the St. Lawrence valley. From near Gaspe peninsula southwestward 400 miles (643·7 km.) to the Champlain valley, the upper marine limit is marked by weakly built bars of gravel and obscure beaches, never by strong cliffs. This is true even on the exposed headlands. Experience shows that it is a mistake to look for wave-cut benches. Evidently this coast was already rising from the sea when the ice first uncovered it, and the waves did not have opportunity to cut sharply into the shore.

(3) Accurate measurements of altitude on the uppermost gravel beaches in the district between Quebec and Lake Champlain, including that portion of the old shoreline which lies 40 miles (64·4 km.) southeast of Mount Royal, points to the probability that the submergence on this mountain is between 500 and 600 feet(152·4 and 182·8 m.).



Geological Survey, Canada

South shore-line of the Ancient Champlain Sea

Miles
10 0 20 40 60 80 100

Kilometres
10 0 50 100 150

(Scale of map is approximate)



Among the localities east and southeast of Montreal are:—

Roxton, 50 miles (80·5 km.) east of Montreal, 552 feet (168·2 m.).

A point 5 miles (8 km.) southwest of the last, 540 feet (164·6 m.).

Granby, 40 miles (64·4 km.) east of Montreal, 516 + feet (157·2 m.).

Dunham, 45 miles (72·5 km.) southeast of Montreal and 12 miles (19·3 km.) north of the Vermont line, 509 feet (155·2 m.).

Mount St. Hilaire, an isolated island 20 miles (132·2 km.) east of Montreal, 560 + feet (170·7 m.).

Nowhere southwest of Quebec has the highest beach been found above 600 feet (182·8 m.).

An examination of the slopes of Mount Royal shows distinct gravelly beaches in several parts of the city up to 300 feet (91·4 m.) and various benches and cliffs on the steeper higher slopes of the mountain, especially in Mount Royal park. There is little if any reason for regarding these benches and cliffs as wave cut. They are discontinuous, not horizontal, cluttered with cliff debris or clay, not with wave-worn beach deposits, and in short are exactly the sort of benches which one might find at any level on these weathered, glaciated mountain sides. The only favourable place for rapid beach building on the mountain between 500 and 600 feet (152·4 and 182·8 m.) is around the park ranger's house and at the back of the Protestant cemetery. Here light gravelly beaches do in fact occur. The ground is gently sloping and well covered with unconsolidated material. Near the rear gate of the cemetery, excavations along a cart road at 600 feet (182·8 m.) show rough unwaterworn rubble and sand formed by the weathering of the eruptive rock. It is hard to see how this loose material could have been submerged without receiving at least a thin sheet of assorted sediment. Proceeding through the cemetery from this point down the gentle slope one comes within 100 yards (91·4 m.) to a low, yet fairly distinct ridge, the form of which is very much like that of a beach. This was being excavated for burial lots in June 1913, and its gravelly composition was then plainly exposed. It can be traced eastward for 150 yards (135 m.) or more through the cemetery, although it has suffered somewhat from artificial grading. It seems to be the highest place where gravels

occur in the cemetery. Its altitude is 540 feet (164·6 m.) above the city datum, or 564 feet (171·9 m.) above tide.

The park ranger's house stands on the rim of a wide swampy hollow or cove whose floor is a little below 570 feet (173·7 m.). Across the mouth of this cove just north of the park slide is a low, spit-like ridge of gravel. More distinct spits occur at slightly lower levels southwest of the park slide near the southeast corner of the race track. These appear to have been formed by waves beating around the exposed southeast corner of the island, and trailing beach material into the sheltered cove behind it. According to Mr. Ardley, curator of the Peter Redpath Museum, Sir William Dawson's highest shell locality is here, at the point where the park ranger's ditch crosses the gravel spit. The altitude is 568 feet (173·1 m.).

THE UPPER MARINE LIMIT AT COVEY HILL AND VICINITY.

By J. W. Goldthwait.

Covey hill lies 35 miles (56·3 km.) south of Montreal, and only one mile (1·6 km.) north of the New York boundary. It is the northeasternmost hill of the upland of sandstone which flanks the Adirondack mountains of northern New York. Southeast of it is the great lowland of Lake Champlain; southwest of it is the lowland of Lake Ontario. Northwest, north, and northeast of it is the great lowland of the St. Lawrence, which has already been described and which stretches unbroken from Covey hill far beyond Mount Royal

The presence of marine shells in the clays which cover these lowlands on three sides of the Adirondack foot hills indicates that the late Pleistocene sea extended around it in Vermont and New York. Distinct beaches on the slopes of these foothills mark the old shore lines of this sea. The beaches occur, not only at altitudes close to those of localities where shells have been discovered, but at higher altitudes; indeed there seems to be a development of beaches wherever conditions of exposure, slope, and beach material were favorable, up to 525 feet (160 m.). Shells, however, are almost unknown above 300 feet (91·4 m.).

The question of the altitude of the highest marine beach in this district is complicated by the presence both in the Champlain valley and in the Ontario valley of higher shore lines which have generally been referred to temporary pro-glacial lakes, that is to say, lakes in basins whose natural northern outlets were for a time covered by the ice sheet as it withdrew from the lowlands but still overlapped the Covey Hill highlands and those of northern Vermont. According to Professor J. B. Woodworth [**10,** pp. 66-265] the higher beaches of the Champlain valley which would reach Covey hill at an altitude above 700 feet (213·4 m.), if they extended as far north as that, do not continue around the north side of the hill, but seem to vanish some where between West Chazy, New York and the international boundary. It is inferred from this that the ice sheet covered Covey hill while these beaches formed in a "glacial Lake Champlain." On the contrary, according to Professor H. L. Fairchild there are beaches and deltas of a water plane above 700 feet (213·4 m.) on the Ontario side, which may perhaps be carried around the Covey Hill district by correlation with obscure delta deposits and found to correspond with the distinct beaches at West Chazy. The water plane thus restored is believed by Fairchild to be marine, and to extend over the Champlain-Hudson divide at Fort Edward, N.Y. and down the Hudson river to sea level at New York city. The observations upon which Professor Fairchild bases this conclusion have not yet been published. The importance of so critical a correlation of beaches on the Ontario and Champlain sides of the Adirondacks demands for satisfactory support a very large number of accurate measurements of altitude along the shore line in question.

The determination of the upper marine limit at Covey hill can hardly be reached by a search for marine shells however diligent. Rarely have shells been discovered at or near the line of maximum submergence. Montreal and Rivière du Loup are the only localities where this has been the case. Shells can be relied upon simply as an index to the fact that the sea stood at least as high as they occur; the marine beaches ordinarily extend up to much higher altitudes. This is due not simply to the failure to look carefully for shells at the upper limit but apparently to the fact that shellfish were most numerous and best pre-

served in the deeper waters off-shore. In the Covey Hill district shells have been found only as high as 260 feet (72·2 m.). Artificial excavations on both sides of the road, a half mile south of Hemmingford village show a large number of *Saxicava arctica* in a loosely packed deposit of very coarse gravel. The presence of complete shells with valves shut together, standing in attitudes of growth between heavy cobblestones, shows a surprising capacity in *Saxicava* to withstand heavy surf. It is perhaps strange that the shells have not been dissolved away, where so much open space is present. The upper three or four feet of the deposit, however, are barren; and the abundance of shells in the underlying strata may be due to the presence until very recently of the water table at that height. The upper, barren zone, shows considerable oxidation of iron, while the fossil-bearing beds are of blue colour.

A better guide to the upper marine limit consists in the wave-built beaches, which in this district are exceptionally fine. As one approaches Covey Hill village by road from the east, well-built ridges of water-worn sandstone shingle make their appearance. The first of these are near the 300-foot (91·4 m.) mark. From this level up to 525 feet (160 m.) there is a rapid succession of them. A very conspicuous group of them crosses the road near Covey Hill Methodist church, half a mile east of the post office. One upon which the church itself is built is 507 feet (154·5 m.). Below this one, at a barn, are two strong ridges of sandstone slabs, at 500 and 496 feet (152·4 and 151·2 m.). Although the slabs of rock are poorly rounded, their imbricated structure shows plainly that they have been slapped up into their present positions by wave action. The crests of the beaches are very uniform, and their front and back slopes very graceful. About 250 yards (228·6 m.) from the church farther up the road is the highest beach of all, at 524 feet (159·7 m.). This is distinct, although not as conspicuous as the lower beaches, because it has very little back slope. On the road which runs northward from the post office, a similar series of beaches is crossed, which correspond closely in altitude to those just mentioned. In descending order these are 524, 517, 506, 500, and 455 feet (159·4, 157·6, 154·2, 152·4, and 138·7 m.). The beach form and the wave-worn shape

of the beach material improves with each successive shoreline, as it naturally would do because of the working over in the lower beaches of materials dragged down the slope by the retiring sea. There appear to be no signs of wave action above the 524-foot beach, unless an obscure terrace at 530 feet (161·5 m.) can be thus reckoned. These beaches appear again with full strength and with corresponding height near Stockwell, four miles (6·4 km.) west of Covey hill. Where a road turns due south toward Geraldine, there is a stony pasture in which ridge after ridge rise with characteristic beach forms to the uppermost one at 523 feet (159·0m.). They can easily be traced to Franklin Center, four miles (6·4 km.) farther west, where the altitude of the uppermost one is 525 feet (160 m.). Evidently the 525-foot beach of this district is a continuous one through the stretch of eight miles (12·9 m.).

Since the group of beaches which has just been decribed extends without interruption from 525 feet (160 m.) down to the level of the shell locality at Hemmingford, there appears to be no good reason for not accepting the whole series as marine. Because there appears to be a complete absence of distinct marks of wave action above the 525-foot beach it seems probable that this one marks the upper marine limit at Covey hill.

The strength of the Covey Hill beaches is phenomenal, owing not so much to the wide open exposure to wave action which this hill afforded during the submergence of the St. Lawrence lowland, as to the presence of an abundance of hard discoidal sandstone debris which the waves found it easy to pack up into beach ridges. The contrast between the beaches here and the very obscure strands which mark the opposite shore, northeast of Lake Champlain, makes it evident that, where the sea has washed against disintegrating ledges of slate like that which prevails between Lake Champlain and the city of Quebec, the waves have not had opportunity to construct distinct beaches.

A comparison of the upper marine limit at Covey hill, at 525 feet (160 m.), with the highest beach on Mount Royal, 568 feet (173·1 m.), and the localities northeast of the Champlain valley, given on an earlier page, shows a fair degree of harmony among them. Assuming that all mark the same water-plane, the uplift of this ancient sea-level between Covey hill and Montreal amounts

to 43 feet (13·11 m.) in 35 miles (56·3 km.), or 1·2 feet per mile (·23 m. per km.) in a direction about S. 10° W.

On the upland southwest of the top of Covey hill is a broad, deep gorge known as Covey gulf, which has played an important part in the history of the drainage of the St. Lawrence system. Through it the combined waters of the glacial Great Lakes appear to have discharged, while the ice front stood against the north side of Covey hill and dammed the whole upper St. Lawrence. In the floor of the gulf are two deep pools of water marking the positions of plunge pools of the ancient Niagara. The altitude of the lower of these pools is approximately 870 feet (265·1 m.). The river which excavated the gorge must have discharged into a body of water in the Champlain valley whose surface was at least as low as this, not improbably the "Glacial Lake Champlain," which later disappeared when the ice withdrew from the highland north of Vermont and allowed the sea to come in from the Gulf of St. Lawrence. The relation of this abandoned gorge to the higher water-levels of the Ontario and Champlain basins and to the later marine levels of the Champlain sea will be fully discussed in the field. Pending the publication of conflicting observations and conclusions, it seems best not to state in detail the views now held by those who have been carrying on investigations in this field.

THE SUPERFICIAL DEPOSITS NEAR OTTAWA.

by

Joseph Keele and W. A. Johnston.

GEOLOGY OF THE SUPERFICIAL DEPOSITS.

Glacial Deposits.

The superficial deposits of the city of Ottawa and vicinity consist principally of gravels, stratified sands, and clays and boulder clays.

The boulder clays were deposited by ice sheets advancing from the Pre-Cambrian upland in a general southwest direction across the Ottawa valley. That the

predominant movement of the ice sheets was in a southwest direction is shown by the general trend of striae and the frequent occurrence of "stossing" of glaciated rock surfaces on the north side. Other striae, which are more local and generally confined to the valley of the Ottawa river, show a movement of the ice in a direction nearly at right angles to this. The two sets of striae are rarely seen on the same rock surfaces in the vicinity of Ottawa, but farther west they are frequently seen crossing each other, and the older course is towards the southwest, while the more recent courses are towards the southeast and appear to have been influenced in their direction by the river valleys.

How many repetitions of glaciation in Pleistocene time there were in this area is not known, but the presence of two till sheets, separated by stratified sands and gravels shows that at least two ice invasions occurred, which are presumably the most recent, and it is possible that there were others of which no record remains.

The boulder clay ascribed to the earlier invasion of the ice sheet is the lowest member of the surface deposits. The boulders of this deposit, which are usually small, are imbedded in a stiff gritty clay, forming a compact resistant material. It occurs in large patches, not in a continuous sheet, and is rarely exposed except in excavations or along river banks. This boulder clay where present generally rests on comparatively fresh rock surfaces, often polished, striated and grooved, and no evidence of residual clays, soils or gravels of pre-glacial age have been found in the district.

Sections of the drift at Ottawa which include the upper boulder clay show it resting on horizontally stratified, or crossed bedded, soft, incoherent sand beds. The upper boulder clay carries many larger boulders, has a larger proportion of rounded stones and contains less clay in the matrix than the lower boulder clay. The erosive action of the ice sheet during its later advance was feeble, for it passed over sand and clay beds with little damage to these soft materials. The principal work accomplished seems to have been the pushing forward and transportation of loose drift materials derived from the earlier ice invasion.

Marine Deposits.

Following the withdrawal of the last ice sheet a long arm of the St. Lawrence embayment extended far up the Ottawa valley. Marine sediments are widespread in the Ottawa district, and at many places shells of marine species are abundant in the sands and clays which were deposited during this submergence. To what height the district about Ottawa has emerged from the sea since the withdrawal of the ice, and how far westward the embayment extended have long been disputed questions. Marine fossils have been found at various places in the district to a height of 475 feet (144·7 m.) above sea level, but the upper limit of marine submergence has been generally put considerably higher. Baron de Geer in his determination of the highest marine shore line near Kingsmere lake, a few miles north of Ottawa, placed the upper limit in the Ottawa district at 705 feet (215 m.) above sea level [**2**, p. 469]. Sir William Dawson [**3**, p. 294], Dr. Chalmers [**4**, p. 68] and Dr. Ells [**6**. p. 222], all maintained that the minimum limit of submergence was at least 1,000 feet (305 m.), and that the Pleistocene sea extended westward over the greater portion of Ontario.

These views as to the extreme height of submergence were apparently based on the general similarity of the unfossiliferous sands and clays at high levels to the undoubted marine sediments at lower levels and the occurrence of waterworn gravel and transported boulders at high altitudes, rather than upon the determination of the height of any definite strand lines.

Of late years comparatively little field work has been done in this district. Partly for this reason, partly because, as has been found in the lower St. Lawrence valley, the upper marine strand line is but faintly marked by wave built features and hence is difficult to locate with any degree of certainty, and partly owing to the widely divergent views held on the subject, it can only be stated that the upper limit of marine submergence near the city of Ottawa was not less than 475 feet (144·7 m.) and was probably higher, though there seems to be little evidence that it greatly exceeded this height.

The highest point in the city of Ottawa is Parliament hill on which the parliament buildings are situated, and

during the time of maximum marine submergence this point was submerged to a depth of over 200 feet (60·9 m.).

Some of the highest localities at which marine organisms have been found in the sands and clays of the Ottawa district may be briefly stated. In a cutting a short distance north of Chelsea station on the Gatineau Valley railway, about nine miles (14·5 km.) north of Ottawa, stratified sand, interbedded with clay, contains an abundance of marine shells, the commonest of which are *Saxicava rugosa* and *Macoma fragilis*. These deposits have an altitude of about 425 feet (125·9 m.) above sea level. About six miles (9.7 km.) south of Ottawa along the Rideau river a section is exposed showing 70 feet (21·3 m.) of stratified clay followed by 40 feet (12·2 m.) of stratified sand rich in similar marine fossils, the whole reaching a height of 350 feet (106·6 m.) above sea level. Near Smith Falls, about 45 miles (72·4 km.) southwest of Ottawa, the bones of a whale have been found in a sand and gravel deposit at a height of 440 feet (134·1 m.) above sea level. Marine fossils are also recorded near the village of Galetta, about 30 miles (48·3 m.) west of Ottawa, at an altitude of 475 feet (144·7 m.), which is so far as known the highest point at which marine fossils have been found in the district.

Above the highest point at which marine fossils are found in the vicinity of Ottawa the slopes and character of the surface are unfavourable for the record of wave built features. Below this altitude, however, well defined, though not strongly built beach ridges and terraces, marking short pauses in the emergence of the land from the Pleistocene sea, frequently occur. Several of the terraces are well seen seen along Gatineau river a short distance north of Hull, across the river from Ottawa.

The marine sands and clays are widespread in the Ottawa district and at some points are known to attain a maximum thickness of nearly 200 feet (60·9 m.).

The clays are found either unconformably overlying the boulder clay or resting on bed rock. Occasionally layers of gravel or sand are interposed between the boulder clay and the overlying clay.

The clays are bluish grey toward the bottom of the deposit, changing toward the top to rusty grey or brown, owing to oxidation of their iron content. Stratification is a pronounced feature of a portion of the clays, but

other portions show little or no evidence of this, being massive jointed clays. They are very plastic when tempered with water and when mixed with a small proportion of sand are easily moulded. They are impure and easily fusible, so that no higher grade of structural wares than common brick or field drain tiles can be made from them.

Local Descriptions.

The best known localities for marine clay near Ottawa are Green's creek and the shore of Ottawa river at Besserer's wharf, a few miles below the city. At these localities the clay affords great numbers of calcareous concretions which are often found to contain the skeleton of a fish, the commonest species being the capelin still numerous in the lower St. Lawrence. Other nodules have been found to contain plant remains and a considerable flora has been obtained from them. Insects, feathers, bones of birds and bones of seals are found also, but very rarely. The clay in this vicinity is known to have a thickness of at least 140 feet (42·6 m.). The river is here about 118 feet (36·0 m.) above the sea, and the clay banks rise from 20 to 40 feet (6·1 to 12·2 m.) above the water. Similar concretions have been found up the Ottawa river, about 60 miles (96·5 m.) northwest of the city, where they occur at an elevation of 370 feet (112·7 m.).

The marine clays are well seen in terraces along Gatineau river a short distance north of Hull. Brickyards in Ottawa also give excellent exposures of the clay from which a great number of marine fossils have been obtained, including several species of shells, silicious spicules of a sponge and foraminifera. Altogether 28 kinds of plants and at least 33 animals are known to occur in these clays. It should be stated, however, that the great mass of the clay is almost barren of fossils and, except in favoured localities, the marine fossils are mostly confined to the sandy layers near the top of the deposit.

The clay, which is looked upon as a comparatively deep water deposit, is overlain by stratified sands and gravels which were in part deposited along shore lines and as shoals in shallow water during the period of emergence of the land. Marine shells are common in the sands at some localities and are as a rule most numerous

towards the bottom of the deposit near its junction with the clay. The sands are generally somewhat barren, however, or contain only a few shallow water species.

In some instances the sands rest on boulder clay or directly on the rock which is often striated below the deposit. When the sands rest upon the clay, as is not infrequently the case, the contact may be either of two kinds. In most cases there is a transition from one deposit to the other, the clay becoming sandy and gradually passing upwards into pure sand and fine gravel. In other cases the surface of the clay has been deeply trenched, apparently by stream erosion, the channels afterwards being filled with cross-bedded sands and gravels. A good example of this is shown by a section uncovered near the sulphite plant of the Eddy paper works in Hull. In such cases the sands and gravels, which are local in character and distribution and have not been found to contain marine fossils, are supposed to be due to stream deposition.

Stratified and unstratified sands and gravels, which are considered to be glacial in origin, also occur in the district. Travelled boulders are numerous, either imbedded in the sands and gravels or lying loose on the surface at all elevations.

It is generally believed that the marine sands and clays were deposited during the time of submergence at the close of the Glacial period and that they were never overlain by a later till sheet. Drift boulders occasionally rest on these beds, but their occurrence may be explained on the supposition that they were carried to their present positions by floating ice during the time of marine submergence or by stream action aided by ice. On account of the general absence of boulder clay from the surface of the clays and the well perserved character of many of the marine strand lines, it does not seem probable that any extensive ice invasion took place after the deposition of the clays. It is possible, however, that local ice tongues advanced from the highlands during the time of marine submergence, or after the partial subsidence of the marine waters and the occurrence of the moraine-like deposit which overlies marine clay and is well seen in Hull, may possibly be explained on this supposition.

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The city of Hull is built partly on a ridge of Trenton limestone and partly on a series of wide flat-topped boulder ridges somewhat resembling small terminal moraines.

A section of one of these ridges near a quarry in Trenton limestone shows 10 to 20 feet (3·0 to 6·1 m.) in thickness of large angular blocks of limestone, occasional well rounded boulders of Pre-Cambrian rocks, and a small quantity of waterworn gravels and stones. The limestone slabs lie mostly in an imbricated manner, as if they had been acted upon by some powerful thrust. The following section is from the most southerly ridge near Chaudière street and is in descending order:—

1. Large angular blocks of limestone mixed with sand, gravel, and an occasional rounded boulder of granite, etc., 8 feet (2·4 m.).
2. Fine sand and gravel, 2 feet (·6 m.).
3. Fine, tough, bluish, stratified clay containing marine fossils, 1¼ feet (·4 m.)
4. Boulder clay, 3 feet (·9 m.).
5. Limestone rock in place, glaciated, striae, course S. 60° E.

Northeast of this locality, or toward Gatineau river the sections of the ridges show waterworn boulders of smaller size and far more Laurentian pebbles than does the one just described. These deposits are spread out fanwise on an eroded surface of marine clay.

These ridges have been described by Dr. Chalmers [5] and W. J. Wilson [7], and were considered by Dr. Chalmers to be due to both sea-borne and river ice. Mr. Wilson regarded them as possibly of morainic origin.

On account of the unglaciated character of most of the boulders of the deposit, the imbricated position of the boulders suggesting current action, and the general absence of clay in the matrix, the more probable explanation of the occurrence of the ridges seems to be that they are due to river deposition aided by ice action during a late stage of the marine submergence or at a time when the waters of the Ottawa and Gatineau rivers stood at a higher level than they do at present.

Stratified sands and gravels overlain by boulder clay also occur in the Ottawa district and are hence regarded as interglacial in age.

A good section of the upper boulder clay is exposed at the Canadian Northern Railway station, about one

mile (1·6 m.) southeast of the Parliament buildings. The principal feature of the boulder clay is the quantity of large limestone boulders which, unlike those of the Hull deposit, are rounded and show marks of strong glaciation. The matrix in which the boulders are imbedded, although very sandy, is stiff enough to sustain the material in a perpendicular face. The boulder clay, which is overlain by a few feet of yellow stratified sand, includes layers of irregularly bedded sands which appear to divide the boulder deposit into two sheets.

A sand pit on the south side of Rideau river about, one mile (1·6 km.) southwest from the Canadian Northern Railway station, exhibits an excellent section of irregularly bedded sands and gravel overlain by the upper boulder clay. The boulders are much smaller and better rounded in the boulder clay of this deposit than in the one last described, and the quantity of clay in the matrix is greater, but it is a more friable deposit than the lower, older sheet. The variation in bedding and the alternation of material in the underlying sands and gravels at this locality are remarkable, and they are said to be at least 30 feet (9·1 m.) in thickness.

Drainage Features.

The principal drainage features of the district may be explained briefly as follows:—

The Ottawa river in the vicinity of Ottawa flows in an easterly direction at the base of the limestone escarpment fronting the old land to the north, and occupies a post-glacial channel in the sense that the probable pre-glacial course of the Ottawa or its predecessor was several miles to the south, where well borings show the presence of a broad, deeply drift-filled valley. The limestone escarpment, however, is believed to be for the most part pre-glacial in origin and due to stream erosion through a protracted period in pre-glacial times.

In post-glacial time it is probable that the Ottawa river has cleaned out and somewhat deepened the old valley in the vicinity of Ottawa, and the steepwalled gorge which extends for a short distance below the Chaudière falls is evidently due to post-glacial erosion.

Rideau river, coming from the south, occupies a shallow post-glacial valley, flows across the old drift

filled valley of the predecessor of the Ottawa and enters the Ottawa near the eastern end of the city with a fall over the rock escarpment of about 50 feet (15·2 m.).

Gatineau river, coming from the north and entering the Ottawa nearly opposite the mouth of the Rideau, appears to follow its pre-glacial course, an ancient valley carved in the resistant rocks of the Pre-Cambrian upland. Like all the rivers flowing from the upland into valleys floored with Palæozoic rocks it has its steepest grade near the contact of the Pre-Cambrian with the softer rocks.

ITINERARY OF EXCURSION.

Leaving Dufferin bridge on a C.P.R. local trolley car and crossing the Interprovincial bridge to Hull, sections in a boulder ridge and a quarry in Trenton limestone are first examined. Southeastward about a quarter of a mile from this point several sections of boulder ridges may be seen. Proceeding by trolley car to the sulphite plant of the Eddy paper works, a section showing cross-bedded sands and gravels filling erosion channels in marine clays may be examined next.

Returning by street car to Ottawa over the Chaudière Falls bridge and proceeding from the end of the Bank street line southward to a sand pit near Rideau river, a section of till overlying stratified sand and gravel may be examined.

ALTERNATIVE EXCURSION.

By taking the boat from Queen's wharf down Ottawa river to Besserer's wharf, the marine clay at the latter point may be examined and concretionary nodules containing marine fossils collected.

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EXCURSION A II.

ORDOVICIAN OF MONTREAL AND OTTAWA.

BY

PERCY E. RAYMOND.

CONTENTS.

	PAGE.
Introduction	138
Table of formations	138
Description of formations	139
Potsdam	139
Beekmantown group	139
Theresa	139
Beauharnois	140
Chazy	140
Black River group	141
Pamelia	141
Lowville	141
Black River	141
Trenton group	142
Dalmanella beds	142
Crinoid beds	143
Tetradium beds	143
Prasopora beds	143
Cystid beds	143
Sponge beds	143
Utica group	144
Collingwood	144
Utica	144
Lorraine group	144
Richmond group	144
Bibliography	145
Montreal and vicinity	145
Parc Laval and St. Martin Junction	145
Mile End	146
St. Vincent-de-Paul	147

PAGE

Pointe Claire and Ste. Anne-de-Bellevue..... 148
St. Helen island..... 149
Ottawa and vicinity..... 150
Hull..... 150
Cummings Bridge..... 151
Rockcliffe..... 151
Mechanicsville..... 152
Governor bay..... 153
Chaudiere falls..... 154
Parliament hill..... 155
Tétreauville and "The Heap"..... 155
Montreal road..... 156
Britannia and Westboro..... 157
Aylmer and Queen's Park..... 158
Division street and Dow lake..... 159
Hogsback..... 159
Hawthorne..... 160
Vars..... 160

INTRODUCTION.

The great expanse of low, nearly flat land, which borders the St. Lawrence and Ottawa rivers for 200 miles (322 km.) above and below the mouth of the Ottawa, is underlain by strata of Upper Cambrian and Ordovician age. While the greater part of this area is covered with boulder clay or marine sands and clays of Champlain age, there are many exposures along and near the rivers, and good sections of all the Ordovician formations may be seen within a radius of 20 miles (32 km.) of either Montreal or Ottawa.

TABLE OF FORMATIONS.

ORDOVICIAN.

Richmond	Richmond.
Lorraine	Lorraine.
Utica	Utica.
	Collingwood (Ottawa).

Trenton	Sponge beds (Ottawa).
	Cystid beds (Ottawa).
	Prasopora beds.
	Dalmanella beds.
	Trinucleus beds (Montreal).
	Parostrophia beds (Montreal).
Black River	Black River.
	Lowville.
	Pamelia.
Upper Chazy	Aylmer.
Beekmantown	Beauharnois.
	Theresa (Ottawa).
Upper Cambrian.	
Potsdam	Potsdam.

DESCRIPTION OF FORMATIONS.

Potsdam.

The Potsdam sandstone is a very hard, white to yellow sandstone, made up largely of quartz sand, cemented by silica. It contains few fossils in Canada, *Lingulepis acuminata* being the only common one. Large and well marked trails, supposed to have been made by huge mollusks, are not uncommon. They were first discovered and are still to be seen at Beauharnois, not far from Montreal. The Potsdam sandstone is employed with good effect as a building stone, and examples of its use may be seen in the Government buildings at Ottawa.

Beekmantown Group.

Theresa.—In some parts of the Ottawa valley the oldest beds of the Beekmantown are composed of reworked Potsdam sand, with a calcareous cement. These beds are therefore softer and weaker than the Potsdam beds. They contain fossils at several localities, the more common of which are *Ophileta complanata* and *Pleurotomaria canadensis*. The upper part of the Theresa is a thin-bedded, gray dolomite, with the same fossils. The Theresa is absent from the section at Montreal, and is thin near Ottawa, but thickens southward, toward Smiths Falls and Brockville.

Beauharnois.—The Beauharnois is probably a composite formation, and a great deal remains to be done on its stratigraphy and fauna. At the typical locality, along the Beauharnois canal, southwest of Montreal, it consists of dolomite and rather pure, blue-black limestone, with a fauna allied to that of the Beekmantown at Beekmantown, New York, and indicating a position low in the Lake Champlain section. Some of the typical fossils in this region are *Hormotoma anna*, *Holasaphus moorei*, *Isoteloides whitfieldi*, *Bathyurus angelini*, *Ophileta complanata*, and several ostracods. Farther west, in the vicinity of Ottawa, the strata are more sandy and there is more light gray, rusty dolomite. The fauna here has some species like the eastern ones, but *Protocycloceras lamarcki*, *Pleurotomaria canadensis* and other mollusca dominate the assemblage. It hardly seems probable that there is anything as modern as the Fort Cassin fauna of the Lake Champlain section in the Ottawa or St. Lawrence valleys.

Chazy.

Aylmer Formation.—The greater part of this formation consists of sandstone and shale, the beds at the base containing in places very coarse material, as in the vicinity of Grenville, Quebec, and Hawkesbury, Ontario, where the contact between the Aylmer and Beauharnois is well shown. The sandstone is not well exposed around Montreal, but may be seen at a number of places in the immediate vicinity of Ottawa. The sandstone has a considerable fauna, a part of which is known only from the Ottawa valley, but there are a few species which are common to this sandstone and the Upper Chazy limestone of the Champlain valley, and still more which range throughout the sandstone and limestone of the Aylmer formation. The limestone in the upper part of the formation is well developed at Montreal, but thins westward, so that at Ottawa the calcareous member of the formation is very unimportant. In the vicinity of Montreal and as far west as Hawkesbury, the limestone is hard, fairly pure, thick-bedded, and frequently a solid mass of such Upper Chazy fossils as *Camarotœchia plena*, *Camarotœchia orientalis*, *Malocystites murchisoni*, *Sigmacystis barrandei*, *Sigmacystis emmonsi*, *Bolboporites americanus*, *etc.* About Montreal this limestone is extensively quarried at St. Martin Junc-

tion, Bordeaux, Outer Mile End, and Caughnawaga. As one follows the limestone westward beyond Hawkesbury it becomes thinner, less fossiliferous, and less pure, and west of Ottawa it has not been reported. At Ottawa it still carries *Camarotœchia plena*, but no cystid has been seen west of Rockland, which is 30 miles (48 km.) east of Ottawa.

Black River Group.

Pamelia.—At Ottawa, the thin limestone of the upper Chazy is succeeded by a formation which is shaly and sandy in its lower portion, but consists chiefly of limestone. There are two easily recognized divisions; a lower, composed of dark blue and gray limestone full of ostracods, with sandy shales at the base, and an upper consisting of light buff, fine-grained, pure limestone alternating with beds of bluish magnesian limestone, which weathers yellow. At the base of the upper division is a bed of coarse sandstone. Neither division contains a great variety of fossils, but such species as are found are more nearly akin to the Lowville and Black River faunas than to the Chazy. As this formation is traced eastward it becomes thinner. The last actual outcrop seen in that direction is at L'Original, and at Montreal the Lowville rests directly upon the limestone of the Aylmer formation.

The principal fossils of the lower division are *Beyrichia clavigera* and other ostracods, *Bathyurus acutus*, and *Helicotoma whiteavsiana*. In the upper part *Isochilina armata*, *Leperditia fabulites*, *Bathyurus superbus*, *Tetradium*, and other fossils are found.

Lowville.—The Lowville is a thin formation, consisting mostly of buff, fine-grained, rather pure limestone, with an occasional shaly bed. It is characterized by a great abundance of *Tetradium cellulosum*; *Bathyurus extans* is also a typical fossil. Though only 15 to 30 feet (4·5 to 9·1 m.) thick, the Lowville is very persistent in this region, but disappears to the north-east, where it is absent from the section at Joliette, 50 miles (80·4 km.) north-east of Montreal.

Black River.—This is another thin formation, consisting of thick beds of rather impure, gray to black limestone. The fauna is a large one, some of the more common and characteristic species being *Columnaria halli*, *Hormoceras*,

tenuifilum, *Bumastus milleri*, *Dalmanella gibbosa*, and *Strophomena filitexta*.

The Black River at and north of Montreal agrees with the Leray formation of New York in having an abundance of flat, disk-shaped masses of black chert; but west of Montreal and in the vicinity of Ottawa the chert seems to be absent. The formation is from 30 to 40 feet (9·1 to 12·2 m.) thick.

Trenton Group.

The Trenton at Montreal is very different from the Trenton at Ottawa, and the exposures in the region between the two cities are so poor that the correlation had to be made through the Champlain and Mohawk valleys, around the Adirondacks into central Ontario, and thence to the Ottawa section. As a result of this correlation, it appears that the oldest beds in the Trenton at Ottawa are younger than the lower 100 feet (30·4 m.) of the Trenton at Montreal; that is, that the *Dalmanella* beds at Ottawa are younger than the *Trinucleus* beds at Montreal (see table above) and that the "Trentons" of the two cities correspond only in a general way. At Montreal, the lower part of the Trenton is well shown, but the upper part is exposed badly or not at all. All the strata there are rather thin-bedded, blue-black limestones, and the lowest beds contain the fauna with *Parastrophia hemiplicata*. A thickness of about 40 feet (12·2 m.) of these strata is overlain by some 50 feet (15·2 m.) of limestone with *Trinucleus concentricus*, *Triplecia nuclea*, *Trematis terminalis*, and other fossils. This same zone can be traced as far west as Trenton Falls in New York, where it is at the very base of the typical section, but it is unknown farther west. At Trenton Falls and elsewhere in New York, this zone is succeeded by the fauna with *Triplecia extans* and *Triplecia cuspidata*, *Orthis tricenaria*, *etc.*, which is the *Dalmanella* fauna at the base of the Ottawa section. Whether or not this fauna is present at Montreal has not yet been determined, but the next zone, with the *Prasopora* fauna, is probably continuous over the whole area. At Montreal the exposed section stops with the lower part of the *Prasopora* beds.

At Ottawa, the following zones have been recognized, beginning with the lowest:—

Dalmanella Beds.—Thin-bedded, pure, blue-black limestone, characterized by *Orthis tricenaria*, etc. These

beds are very poorly exposed at Ottawa, and have an estimated thickness of about 40 feet (12.2 m.). They are well shown above the Black River in the Stewart quarry at Rockland, and were also seen on top of the Black River at Fenelon Falls and Kirkfield lift-lock in central Ontario.

Crinoid Beds.—Thick and thin-bedded blue limestone, with a large amount of chert, developed as flat plates parallel to the bedding. These beds are particularly well shown in Hull, and furnish a large part of the building stone and crushed stone used in Ottawa. Just at the top of these beds are the layers from which a large part of the crinoids found in Hull have been obtained. Strata with the same fauna as these beds occur in central Ontario at Fenelon Falls and the Kirkfield lift-lock, where they occupy the same stratigraphic position as at Ottawa. The thickness of these beds is about 65 feet (19.8 m.).

Tetradium Beds.—Massive, coarse-grained, blue-gray limestone with few fossils. This is the horizon in which are located the large quarries on Montreal road, 3 miles (4.8 km.) east of Ottawa. The same beds are exposed in Hull, but are not quarried at the present time. They seem to be absent from the section in central Ontario. The most common fossil is a species of *Tetradium*, very like *Tetradium cellulosum*. The thickness is about 35 feet (10.6 m.).

Prasopora Beds.—Very thin-bedded limestone, with thick shale partings, characterized by abundant large bryozoans of the genus *Prasopora*. This bed seems to have a very wide distribution, and the fossils are well preserved. In spite of their thin-bedded and shaly character, the strata of this zone are extensively quarried. The thickness of the zone is small, usually not more than 25 feet (7.6 m) and frequently less.

Cystid Beds.—Rather thin-bedded light gray limestone with thin shale partings. In the lower portion is the zone with *Pleurocystites* and *Agelacrinites*. Thickness, about 75 feet (22.8 m.).

Sponge Beds.—Heavy-bedded, fine-grained limestone with clay irregularly distributed through it. These layers weather into an irregular rubbly mass, and are characterized by *Hormotoma trentonensis*, *Rafinesquina deltoidea*, and *Cyclospira bisulcata*. The thickness is about 75 feet (22.8 m.).

Utica Group.

Collingwood.—This formation is not present at Montreal; but at Ottawa and in southern Ontario the Trenton is succeeded by a thin formation, 25 to 50 feet (7.6 to 15·2 m) thick, characterized by the asaphoid trilobite, *Ogygites canadensis*, and several other fossils of a type more common in Europe than America. Among them may be mentioned the plicated *Triplecia*, *Oxyplecia calhouni*, and *Schizambon canadensis*. *Dalmanella emacerata*, *Leptobolus insignis*, *Zygospira modesta*, *Triarthrus becki* and *Ogygites canadensis* are the more common fossils, the last being the most common of all. In lithology, the Collingwood represents a sort of transition between the Trenton and the Utica, as it consists of alternate beds of limestone and shale, each a foot or so in thickness.

Utica.—Above the Collingwood at Ottawa and the Trenton at Montreal, are 200 to 300 feet (60·9 to 91·4 m.) of thin-bedded, fine-grained, brown and black carbonaceous shale with a small fauna, mostly graptolites. *Climacograptus typicalis*, *Climacograptus bicornis*, *Diplograptus pristis*, *Leptobolus insignis* and *Triarthrus becki* are common forms everywhere, and near Ottawa *Triarthrus spinosus* and *Triarthrus glaber* are also found.

Lorraine Group.

Lorraine.—The Lorraine and Richmond have not yet been studied in any great detail in this area, but the recent work of Dr. A. F. Foerste shows that both groups may be subdivided. In the case of both, exposures are few, as the formations occur in a very flat country, at a distance from rivers.

The Lorraine has been explored to some extent east of Ottawa. It consists of sandstone and shale in thin layers, and contains numerous, thin, calcareous bands. The common and characteristic fossils are *Catazyga erratica*, *Byssonychia radiata*, *Pterinea demissa*, *Cyrtolites ornatus*, and *Isotelus maximus*.

Richmond Group.

At some distance east of Ottawa there are exposures of shales and sandstone containing a large Richmond fauna, the most common and prominent species being the well known *Catazyga headi*.

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MONTREAL AND VICINITY.

Parc Laval and St. Martin Junction.

Miles and Kilometres.

5 m. 8 km. **Mile End.**—Leaving Place Viger station, quarries in Trenton limestone may be seen on both sides of the railroad just before reaching Mile End. Near Bordeaux, a large yellow brick building, which is the provincial penitentiary, comes into sight on the right hand side. From this point on, quarries in Chazy limestone are seen on either side of the railroad.

10 m. 16·1 km. **Bordeaux.**—While crossing the bridge immediately beyond Bordeaux, the Aylmer sandstone can be seen in the bed of the river at the right. This sandstone is here near the base of

Miles and Kilometres.

the Chazy but contain the fauna which at Lake Champlain characterizes the upper division of that group.

10·2 m. 16·4 km. **Parc Laval.**—A low cutting in clayey limestone near this point contains a great number of well preserved cystids, and a little search in the beds should reveal *Malocystites murchisoni* and *Sigmacystis emmonsi*.

13 m. 20·9 km. **St. Martin Junction.**—Quarries situated at the top of the hill near this point are being actively worked, and produce a good building stone, but the strata in some of them are not very fossiliferous. In other quarries, however, where the strata are weathered, the rock is seen to be made up of myriads of plates and fragments of cystids and crinoids. The following species are quite common:—*Malocystites murchisoni*, *Sigmacystis barrandei*, *Sigmacystis emmonsi*, *Hebertella borealis*, *Hebertella imperator*, *Bolboporites americanus*, *Blastoidocrinus carcharidens*, *Camarotœchia orientalis*, and *Camarotœchia plena*. This is a modification of the fauna of the upper of the three divisions of the Chazy on Lake Champlain.

Mile End.

The contact of the Lowville and Black River is well shown at several points in the old quarry at the corner of Christopher Columbus and Bellechasse streets, Mile End. Only about one foot of the top of the Lowville is exposed, which is a light buff, pure limestone, full of *Tetradium cellulosum*. The lowest bed of the Black River is a dirty nodular layer, just above which is a four-inch layer, very full of fossils. The whole thickness of the Black River here is 12 feet (3·6 m.). The upper layers, as seen near Christopher Columbus street, in the middle of the block, are full of plates of black chert. The surface of this chert-bearing layer shows a number of large specimens of *Hormoceras* and *Endoceras*.

In the field across Christopher Columbus street, in line with the unopened part of Rue de la Roche, the lowest beds of the Trenton are exposed. These are thin-bedded

limestones, with *Platystrophia lynx*, *Parastrophia hemiplicata*, *Dalmanella rogata*, and many other forms. This is the same as the oldest Trenton fauna found along Lake Champlain and in the vicinity of Quebec. These lowest beds are well shown in the extensive quarry north of Normanville street, where, however, few fossils can be obtained.

In another large quarry beyond the railway track, the upper beds, about 10 feet (3·0 m.) in thickness, belong to the *Cryptolithus tessellatus* (*Trinucleus concentricus*) zone, the characteristic fossils of which, beside the diagnostic tribolite, are *Triplecia nuclea* and *Trematis terminalis*. The *Parastrophia* beds are about 35 feet (10·6 m.) thick, and the *Cryptolithus* beds 40 to 50 feet (12·2 to 15·2 m.) thick.

The top of the limestone in the quarry is a well striated surface, on which rests a thin layer of boulder clay. Above the boulder clay is a thin, but very fossiliferous layer of *Saxicava* sand, 1 to 3 feet (·3 to ·9 m.) thick.

The Prasopora beds are exposed in two quarries near the corner of Iberville and Masson streets. In the thin bedded limestone of this zone the following fossils may be found:—*Prasoporæ*, *Dinorthis meedsi*, *Platystrophi lynx*, *and Sinuites cancellatus*.

St. Vincent-de-Paul.

Black River and Trenton, with intercalated Igneous Beds.—The lowest strata in the section in this neighbourhood are exposed at the ferry. The beds dip up-stream, and consequently in going in that direction successively higher beds are crossed. The yellow-weathering beds first encountered belong to the Lowville, some layers of which are quite fossiliferous. The contact with the Black River is 600 feet (183 m.) from the ferry, the lowest layer of the upper formation being 4 inches (10 cm.) thick and made up of a solid mass of so-called fucoids or branching sponges. The hard surface of the Black River beds shows well the effects of glaciation.

Near the last of the small summer houses, the beds begin to show plates of black chert, and some of the layers beyond this point are full of them. The surfaces also show large specimens of *Hormoceras*, *Columnaria halli* and other fossils.

Continuing up-stream, the section is now interrupted by a few rods of sandy and grass-covered beach, and then we come upon the little cliff where igneous beds are intercalated in the limestones, just at the contact of the Black River and Trenton. The thin-bedded layers in the upper part of the cliff contain *Platystrophia lynx*, *Parastrophia hemiplicata* and other Trenton fossils. There are four beds of the igneous rock, separated by thin layers of limestone. The igneous beds are of the same material as the dykes at Mile End, and are probably contemporaneous with them. The thickest is 32 inches (81 cm.) thick and quite coarse grained, but it does not seem to have affected the limestone above and below it more than a quarter of an inch from the contact.

Pointe Claire and Ste. Anne-de-Bellevue.

Black River, Lowville, Aylmer Limestone (Chazy), Beauharnois and Potsdam.—In the two large quarries south of Pointe Claire the upper 25 feet (7·6 m.) of strata are Black River, with, however, comparatively few fossils. *Columnaria halli*, *Maclurites logani*, and a few cephalopods are present. The lower 7 feet (2·1 m.) are Lowville, exceedingly rich in fossils, of which *Tetradium cellulosum* and *Tetradium fibratum* make up whole layers. There is also a variety of pelecypods, gastropods and cephalopods. This is the typical locality for *Lophospira daphne*, which is quite common here. *Bathyurus extans*, *Isotelus gigas*, *Orthoceras multicameratum*, and *Orthoceras recticameratum*, are other common forms. There is no great lithological difference between the Lowville and the Black River, and the contact can only be found by observing the range of *Tetradium cellulosum*.

The outcrop of the Aylmer limestone (Chazy), which is on a small point extending into Lake St. Louis, is small and a rather unsatisfactory one. The common fossils found here are *Hebertella vulgaris* and *Hebertella costalis*, occurring in a grey, coarse-grained limestone on the right-hand side of the point. It will be noted that the Black River strata at the quarries dip toward the river, so that there is either a syncline or a fault between the quarries and this exposure of Aylmer limestone (Chazy).

A hundred feet (30·4 m.) west of the station of Ste. Anne-de-Bellevue is a small, water-filled, abandoned

quarry in the Beauharnois dolomite. On the right hand border of the quarry, some fossils can be found in place, but more and better specimens can be obtained from the loose pieces of rock which are scattered about. This is the typical locality for *Hormotoma anna*, *Leperditia anna*, *Holasaphus moorei*, and other species.

The Potsdam can also be examined at this point. In 1912 a sewer excavation on the street exposed both the Beauharnois dolomite and the Potsdam, though the contact between the two was concealed. The Potsdam here is hard and quartzitic, and there are none of the soft transitional layers usually seen between the Potsdam and the equivalent of the Beauharnois farther west.

St. Helen Island.

Fossiliferous Lower Devonian Limestone in an igneous Breccia.—Utica shale occupies the southern end of St. Helen island. The shale is cut by several dykes and is somewhat altered, so that it is more friable than is usual. Close to the dykes there is usually a narrow band of rock which has been altered to hornstone.

On the eastern side of the island is exposed the breccia which occupies the larger part of the island. This rock is composed of angular and rounded fragments of red and black shale, hornstone, limestone, red and gray sandstone, granite, gneiss, and quartzite. The fragments are imbedded in a fine-grained matrix of igneous origin which weathers to a reddish brown.

At the north-eastern end of the island, near the swimming pool, are large fossiliferous blocks of gray, coarse-grained limestone. The most northern and largest of these blocks contains an Oriskany fauna, with *Spirifer arenosus*, *S. montrealensis*, *Eatonia peculiaris*, and many other fossils. A smaller block to the east of this contains a Helderbergian fauna with *Siberella pseudogaleata*, *Spirifer concinnus*, *Leptæna rhomboidalis*, *Stropheodonta becki*, and other species. The general facies of these faunas is much more like their equivalent in Gaspe than in New York.

No strata of Helderbergian or Oriskanian age occur anywhere in this region, but from the presence of these blocks in the breccia, it is believed that such strata once extended over this area. The presence of the blocks is explained upon the theory that they were stoped off from

the parent bed, while the great dyke in which they are enclosed was in a molten condition, and that they either sank of their own weight to the low position they now occupy, or that they were drawn down during the surgings of the intrusive [**3**].

The breccia also contains pebbles of limestone with Trenton fossils, and there are other and smaller pebbles with lower Devonian faunas. Some of these pebbles have weathered out, and may be found loose along the shore, especially on the northern and western sides of the island.

OTTAWA AND VICINITY.

Hull.

Trenton Limestone and the Cement Works.—On leaving the Hull electric station in Ottawa the massive limestone of the uppermost division (sponge beds) of the Trenton can be seen in the cliffs on the right. The same strata are seen in the cliffs above the level of the floor of the Interprovincial bridge, and contain the sponge and *Hormotoma trentonensis* fauna, while the strata below this level belong to the cystid zone and carry *Pleurocystites*.

From the bridge itself can be seen on the one hand the strata of which Parliament hill is built, and on the other the cliffs of Nepean point and other bluffs down the river. The shore on the Hull side is low with no rock exposed.

At the Axe Factory quarry in Hull the contact between the massive beds of the *Tetradium* zone of the Trenton and the thin shaly beds at the base of the *Prasopora* zone is well shown. A fault crosses the floor of the quarry, which lets the strata on the eastern side down about 15 feet (4·5 m.), thus repeating the shaly layers. The shaly layers are very fossiliferous, and this locality has furnished a great variety of fossils, among them the type of *Bumastus billingsi*. The common fossils still to be found are *Prasopora*, several species, *Zygospira recurvirostris*, *Dalmanella rugosa*, *Plectambonites sericeus*, *Parastrophia hemiplicata*, *Ctenodonta levata*, *Calymene Senaria*, and others.

North of this quarry is another situated in the angle between the two railroads. The beds here are about 25 feet (7·6 m.) lower stratigraphically than those in the Axe Factory quarry, and belong to the crinoid zone. This quarry has furnished a large number of crinoids, but

specimens are now rare. Among the more remarkable fossils which have been found here are *Edrioaster bigsbyi*, *Comarocystites punctatus*, *Cyclocystoides halli*, *Isotelus latus* and *Amphilichas cuculus*. The strata in this quarry are rather thick-bedded, coarse-grained, gray limestone, separated by black shale partings in which most of the fossils are found.

Farther north near the concrete bridge, is another quarry showing the cherty beds of the crinoid zone, the whole thickness of which may be seen in the Fleming-Dupuis quarry beyond the bridge.

The upper strata in the quarry at the cement works belong to the cherty "crinoid beds" of the Trenton, but the excavation has been sunk through them and the *Dalmanella* beds, into the upper part of the Black River formation, 90 feet (27·4 m.) below the surface.

Cummings Bridge.

Collingwood and Utica Formations.—Cummings bridge spans the Rideau river on the eastern outskirts of the city of Ottawa. On the western side of the bridge is a fault, not however exposed, between the Trenton and the Utica.

On the east side of the river, 100 yards (91·4 m.) below the bridge, black shale outcrops are exposed on the river bank. *Triarthrus spinosus*, *Triarthrus becki*, and *Leptobolus insignis* are common here, and more rarely one finds *Climacograptus typicalis*. These shales are not in place, but have been obtained from trenches dug in the immediate vicinity.

A few minutes walk along the river above the bridge and at a point opposite the Isolation hospital is an outcrop of the limestone and shale of the Collingwood, a formation which comes between the Utica and Trenton. The common fossils are *Ogygites canadensis*, *Triarthrus becki*, *Dalmanella emacerata*, *Leptobolus insignis*, *Schizambon canadensis*, and *Zygospira modesta*.

Rockcliffe.

Chazy.—To the west of Buena Vista station in Rockcliffe park, near the river, there is a low rock cut beside the path. One of the highest layers in this cut is a partially decomposed, impure limestone, with *Camarotœchia plena* and a few

other fossils. In the cliffs by the water edge below this, a good opportunity is offered of seeing the shale and sandstone which make up the greater part of the Aylmer formation. Some of the sandstone beds are lenticular. Fossils are not abundant at this point, but burrows such as *Rusophycus grenvillensis*, and trails of various kinds are not uncommon.

An excellent section of the rocks, of which these cliffs are made up, is obtained on the road leading from the ferry to the electric railway, and in some of the beds of sandstone at the turn in the road it is possible to find a few brachiopods, chiefly *Camarotœchia orientalis*. Across the road from the station on the electric line is a low bluff, and in the green shale at the base of the bluff, specimens of *Lingula belli* are quite common.

The Aylmer sandstone, which is that occurring on the road to the ferry, is again well exposed in the quarry at the eastern end of the park. Fossils, however, are very rare here.

On Buena Vista road, and in other high-lying parts of Rockcliffe, the Aylmer is capped by the lower layers of the Pamelia. The Pamelia is not ordinarily exposed here, but trenches dug in 1910 reached the layers and brought to light a considerable quantity of fossils. Debris from these excavations is still to be found along Buena Vista and other streets, and some fossils may possibly be obtained from it. The black shale with *Beyrichia? clavigera*, outcrop at the corner of Buena Vista road and Minto place, and a hard limestone with *Loxoceras allumettense*, *Modiolopsis sowteri* and other fossils was found above it along Buena Vista road.

Mechanicsville.

Pamelia, Lowville, and Black River.—Going north on Carruthers avenue in Mechanicsville the strata of the upper part of the Black River are at or near the surface. These strata can be seen especially well near the crossing of the Canadian Pacific Railway, where they have been recently much quarried. The strata are thick-bedded, rather coarse-grained, light grey limestones, in which fossils are very rare.

The Hull-Gloucester fault, which is a strong break, traceable for a long distance east of Ottawa, runs along the

western margin of Nepean bay. At the bay the downthrow is on the east, so that the crinoid beds of the Trenton are brought against the Black River; the displacement being therefore only 50 or 60 feet (15.2 or 18.3 m.). There are, however, several faults parallel to the main one, which considerably disturb the strata to the east and give a steep dip to the beds on the islands in the river. Along the shore to the west is a shallow syncline, which exposes the very fossiliferous strata of the Black River for a considerable distance. Large cephalopods, including *Hormoceras tenuifilum*, are common here, and other fossils such as *Columnaria halli*, *Strophomena filitexta*, *Dalmanella gibbosa*. *Bumastus milleri*, and *Isotelus gigas* can be readily obtained, A great many other species have been found here, and this is the type locality for *Cybele ella*.

Farther west the dip of the beds is reversed, and the Lowville comes out below the Black River. The Lowville here consists of pure, buff-coloured, fine-grained limestone, containing such fossils as *Tetradium cellulosum*, *Bathyurus extans*, and *Bathyurus spiniger*. The lowest layers contain *Beatricea* and *Cyrtodonta huronensis*, as in the section on the hill behind Aylmer. A small fault at this point brings the upper part of the Pamelia against the Lowville. The hard limestone near the water level west of this fault furnished the types of *Bathyurus superbus*. It also contains *Tetradium* and other fossils. Still further along the shore a yellowish magnesian limestone was formerly quarried and used as a natural cement.

Governor Bay.

Trenton, Black River, and Pamelia.—Governor bay is a small indentation in the shore line of Ottawa river near the entrance to Rockcliffe park. The first outcrop encountered in descending to the bay from the electric car barns is the shaly limestone of the *Prasopora* zone of the Trenton. These beds are exceedingly fossiliferous and contain *Dalmanella rugosa*, *Plectambonites sericeus*, *Zygospira recurvirostris*, *Sinuites cancellatus*, *Calymene senaria*, and *Isotelus gigas*. Other fossils, however, can also be found. The *Prasopora* layers rest on the thick gray strata of the *Tetradium* zone, but *Tetradium* itself has not been found here. The strata in the bluff above the *Prasopora* beds belong to the crinoid zone of the Trenton, and the *Prasopora* beds

have been faulted down to the south of them. This fault is exposed at the base of the bluff around the point, where the dip of the strata becomes so steep that the cherty beds below the *Tetradium* beds are brought to view.

Another and greater fault in a gully beyond, exposes the Pamelia limestone. Between these two faults is a small block of nearly horizontal strata with Black River at the base, and *Dalmanella* beds above.

Tetradium occurs in the pure blue limestone of the Pamelia, which is followed by yellow-weathering beds, dipping toward the north and containing few fossils. Above the rusty beds, pure dark limestone layers with ostracods, pelecypods and bryozoa, are again encountered, and these strata may be followed around into a cove, where a concealed fault brings them against the shale and sandstone of the Aylmer.

On the path up from the cove to the electric car station *Camarotœchia plena* may be found in a thin limestone interbedded with green shale above the sandy part of the Aylmer limestone. The limestone of the Trenton is in close proximity to this outcrop, but, though it belongs to a horizon below the *Prasopora* beds, its exact position in the section is not known.

Chaudiere Falls.

Trenton.—Near the foot of the hill on Wellington street the perpendicular cliff of Upper Trenton limestone shows, in its lower part, strata belonging to the cystid beds, and in its upper part the *Hormotoma trentonensis* beds.

On the north side of the river at Chaudiere falls are excellent exposures of the thin-bedded limestone of the cystid zone. *Pleurocystites elegans*, *Agelacrinites billingsi* and other rare fossils are found here, in addition to the more common species. These beds are a continuation of those on the Ottawa side of the river, from which Billings obtained the types of many of his specimens of echinoderms.

The strata on the little island between the two bridges belong to the same zone as the rocks on the north shore of the river, and *Agelacrinites* is found in them. The exposures here show well the way in which the fossils are grouped in little depressions in the irregular surfaces of the layers.

Between this island and the next piling ground there is a small fault, beyond which the cherty crinoid beds are exposed in a quarry at the top of the ridge.

Between this ridge and the next one north is a gully, spanned by an iron bridge. The gully represents a fault by which the cherty crinoid beds are again downthrown on the north side. In the lowest layers on the north side of the iron bridge, crinoids may be obtained from the shale between the layers of limestone.

Parliament Hill.

Faults in the Trenton.—In descending to the water's edge from the Supreme Court at the western end of Parliament hill, the first outcrop is an exposure of the rather thin-bedded limestone of the Cystid zone. Following the shore westward other outcrops of the Cystid beds appear, but instead of being horizontal, as at the first outcrop, they dip to the south. One hundred feet (30 m.) beyond the pier, a fault, with an upthrow on the western side, brings the cherty Crinoid beds up against the Cystid beds. This fault is probably the continuation of one of several faults which are visible on the north side of the river, and is probably the same fault which can be traced through Hull into the Axe Factory quarry near Hull station. This fault, which brings up the Cystid layers again, has a four-foot crushed zone, full of fragments of limestone cemented by very coarse calcite, at the contact of the two zones.

Tetreauville and "the Heap."

Lowville, Black River, and Trenton.—From Tetreauville, which is a station on the Hull Electric Railway, a road leads down to Ottawa river. The strata to the right of the end of this road are mostly Lowville with *Tetradium cellulosum* and opposite the end of the road the basal beds of the Black River with *Columnaria halli* may be seen.

Following these beds down stream for a few rods they are seen to be very fossiliferous, and good specimens may be obtained by breaking up the limestone. *Subulites elongatus*, *Trochonema umbilicatum*, *Bumastus milleri*, *Illænus conradi*, and *Thaleops ovata* are some of the more common fossils.

This outcrop is interrupted by the Hull-Gloucester fault, which crosses at this point. Beyond the first fault and along the shore, the cherty beds of the Trenton are exposed.

Returning to the railway track a good section is exposed in a cutting near the switch. First the cherty beds of the Trenton are seen, then the heavier-bedded strata of the over-lying *Tetradium* zone, and, resting on the latter, the thin and shaly beds of the *Prasopora* zone. The fossils of this zone are very common here, and also at the "Heap", a small pile of debris at the right a few rods farther down the track.

Montreal Road.

Trenton, Black River, and Pamelia.—A powder magazine is situated near the Montreal road two and a half miles (4 km.) from Ottawa. A quarry south of the magazine shows a section of strata which belong at a horizon just at the top of the crinoid beds and just below the *Prasopora* zone. From the presence of a species of *Tetradium* in abundance, these have been termed the *Tetradium* beds. This is the typical locality for *Tetradium racemosum*, and specimens can be obtained in the thin, pure layers in the upper part of the quarry. There is a small fault through the quarry, which causes a downthrow of the beds to the north. In the face of the quarry toward the powder magazine, can be seen a reef of *Stromatocerium*.

Between this quarry and Montreal road a fault brings the highest beds of the Trenton and the Utica down in contact with the *Tetradium* beds. The Utica is exposed just at the corner where this road joins the Montreal road.

The Robillard quarries, which are situated in the same beds just seen at the powder magazine quarry, have been worked very extensively, but contain very few fossils other than *Stromatocerium* and *Solenopora*.

Northward beyond these quarries is another quarry showing the upper beds of the Pamelia formation, from which it is possible to collect specimens of *Onchometopus simplex*, ostracods, and a few brachiopods. A part of the way down the hill, just below the house, is a bed of creamy white sandstone, which is the base of the upper division of the Pamelia, and contains many pelecypods, *Isochilina armata*, and a few gastropods. At the foot of the hill is the Aylmer sandstone.

Returning toward the Montreal road, at a point where the road rises over a low escarpment, with a small quarry

at the right, the contact of the Lowville and Black River may be seen.

Another quarry between the cemetery of Notre Dame de Lourdes and the river shows the cherty beds of the crinoid zone of the Trenton very well, but the same beds are better seen at Hull. Two hundred yards (182·8 m.) farther north near a small brook, is another quarry in the upper division of the Black River. Fossils are very rare here.

Britannia and Westboro.

Aylmer and Pamelia Formations.—On the shore of Lake Deschênes north of Britannia village, a canal has been dug through the lower sandstone strata of the Aylmer formation, and the debris which has been thrown out on either side provides an excellent collecting place. Fossils other than burrows and trails are not very common, but *Lophospira billingsi*, *Isotelus arenicola* and others have been found here.

At the point where the Richmond road crosses the Ottawa Electric Railway tracks is a small excavation in black shale, where specimens of *Beyrichia (?) clavigera* and other ostracods may be obtained.

Near the top of the hill at Westboro a cutting exposes the limestone belonging to the lower part of the Pamelia. At the roots of a bunch of cedars to the left is a small exposure of black shale capped by rusty weathering dolomite, or "cement beds," as they are called here. At the bottom of the hill, a blue-black limestone with wavy, *Stromatocerium*-like structure, can be seen. At a little cove just above the ruins of Skeads' mill one sees the black *Beyrichia (?) clavigera* shale, resting on an impure, yellow-weathering limestone and capped by hard sandy beds. The lowest layers here probably belong to the upper part of the Aylmer formation. An escarpment runs back from this point to the Canadian Pacific Railway tracks. In a little cutting here, and in the fields on both sides of the tracks, is found a great quantity of very fossiliferous limestone of the lower part of the Pamelia, from which quite a number of species can be obtained. This is the type locality for *Bathyurus acutus*.

In following the Canadian Pacific Railway track from this point to Mechanicsville, an opportunity is presented of seeing outcrops of the limestone of the upper part of

the Pamelia, from the upper layers of which ostracods, cephalopods, and a few tribolites may be collected.

Aylmer and Queen's Park.

Beauharnois, Aylmer and Pamelia.—At Queen's Park, on the shore of Lake Deschênes, and on either side of the wharf, there are outcrops of the rusty-weathering dolomite of the Beauharnois formation. By persistent search, gastropods and a few other fossils may be found, but as the fossils occur sporadically, it is not possible to name any particular locality from which they can be obtained.

Just below the wharf at Aylmer is an outcrop of sandstone near the base of the Aylmer formation. This sandstone contains *Camarotœchia plena*, *Camarotœchia orientalis*, and *Hebertella imperator*. At another locality a low cutting in sandstone and shale shows numerous specimens of *Ctenodonta parvidens*, *Modiolopsis sowteri*, and *Lophospira billingsi*.

A small excavation in the ditch to the right of the road and opposite the house of Mr. T. W. E. Sowter, indicates the position of the *Beyrichia (?) clavigera* shale and the base of Pamelia formation. This is the type locality for *Beyrichia (?) clavigera* and its variety *clavifracta*.

Along the ditch on the right hand side of the road from this point to the next corner, there are excellent exposures of the lower dark limestone of the Pamelia. This limestone is here very fossiliferous, some of the layers being composed almost entirely of ostracods. At the next corner north, slabs of limestone with silicified fossils may be found in the fields, and near the top of the hill beyond, a quarry at the right shows the upper beds of the Pamelia.

Just beyond this quarry, along the north-line fence of the same field in which the quarry is situated, there is an outcrop of the beds at the base of the Lowville. One of these beds contains an abundance of *Beatricea*, and another, better shown on the other side of the road, is full of specimens of *Cyrtodonta huronensis*. Beyond the next corner north, the Black River follows the Lowville, but it is hardly worth while visiting, as there are no unusual fossils in it.

Division Street and Dow Lake.

Upper Trenton and Collingwood.—Near the corner of Somerset and Division streets is a quarry in the *Hormotoma trentonensis* beds at the top of the Trenton. This quarry has furnished many rare echinoderms, and is the type locality for *Steganoblastus ottawaensis*, for certain crinoids described by W. R. Billings, and for two species of sponges described by Hinde. The fauna of these beds reminds one strongly of the Black River, *Ischadites iowaensis*, *Trochonema umbilicatum*, *Illænus americanus* and various species of *Subulites* and *Fusispira* being found here. Not all these fossils can be found here, but *Hormotoma trentonensis*, *Rafinesquina deltoidea*, *Illænus americanus*, and *Cyclospira bisulcata* are not uncommon.

In a quarry situated on Division street south of the crossing of the Grand Trunk railway the upper part of the cystid beds is exposed and *Agelacrinites* and *Pleurocystites* are found in them. The western border of this quarry is just on the line of the fault between the Trenton and the Collingwood, and this fault crosses Division street just below Norman street.

The low area below Rochester and Preston streets at the north end of Dow lake is underlain by the Collingwood formation, and as extensive sewer trenches have been dug here in the last few years, a considerable amount of fossiliferous material is available along the streets in this district. This is the type locality for *Oxyplecia calhouni*, and entire specimens of the characteristic Collingwood asaphoid, *Ogygites canadensis*, have been found here. The upper Trenton beds come in beneath the Collingwood west of Preston street and Dow lake, and when the water is drawn off, the western side of Dow lake is an especially good collecting ground for *Cyclospira bisulcata*.

The upper part of the cystid zone and the lower part of the *Hormotoma trentonensis* zone are exposed in quarries on Carling avenue, LeBreton and Bell streets.

Hogsback.

Aylmer and Pamelia Formations.—Hogsback is a point on the Rideau river south of Ottawa where the Rideau canal leaves the river. The strata in the bed of the river at Hogsback form a low

anticline which is broken by two or three small faults. Standing at the small stairway near the middle of the bridge and facing down stream, the strata to the right belong to the Pamelia, and those to the left to the Aylmer formation. The small faults mentioned show a drop in each case on the eastern side, except in one instance on the eastern side of the stream, where there is a drop to the west of about 4 feet (1·2 m.).

The strata of the Aylmer formation, on the western side of the stream, consist of sandstone and shale with many burrows and trails. The strata directly north of the principal fall also belong to the Aylmer formation, and contain calcareous beds with *Camarotœchia plena* and other fossils.

Across a fault to the east of these beds are dark limestone and shale with many ostracods, *Helicotoma whiteavesiana* and *Bathyurus acutus*. Above these layers are two thick beds of sandstone, containing pelecypods, and then a dark, wavy bedded limestone, the same layer as is seen so well at Westboro.

At the top of the hill on the road leading from Hogsback to the main road, is a quarry in the Black River limestone where a few fossils may be obtained.

The real Utica may be seen in the bed of a small stream entering Rideau river at Billings Bridge. In the brown and black carbonaceous shales here, graptolites, *Triarthrus spinosus* and *Triarthrus becki* are readily obtained.

Hawthorne.

Lorraine Formation.—Hawthorne is a small station on New York and Ottawa Railway 5 miles (8·0 km.) east of Ottawa. Along the brook about half a mile south of the station, there are several outcrops of shale with thin calcareous layers. Fossils are abundant, and include *Byssonychia radiata*, *Catazyga erratica*, and *Isotelus maximus*.

Vars.

Richmond Formation.—Vars is situated on the Grand Trunk Railway 17 miles (27·3 km.) east of Ottawa. Many fossils of Richmond age may be obtained from an excavation in shale and limestone on a small brook a short distance southwest of the station. At other localities in this vicinity there are several outcrops of very fossiliferous strata of this formation.

LIST OF ILLUSTRATIONS.

Maps.

	Page.
Grenville sheet, Ontario and Quebec.....(in pocket)	
Monteregian hills.....	32
Montreal.....(in pocket)	
Mount Johnson.....	65
Route map between Buckingham and Emerald mine (in pocket)	
Emerald mine, Buckingham township, Quebec.....	89
Route map between Papineauville and Côte St. Pierre.....	93
Côte St. Pierre.....	97
Walker mine, Buckingham township, Quebec.....(in pocket)	
Dominion mine, Buckingham township, Quebec.....	105
Route map, Cantley, Quebec.....(in pocket)	
Nellis mine, Cantley, Quebec.....	113
South shore line of ancient Champlain sea.....	121
Part of Mount Royal showing upper marine beaches (in pocket)	

Drawings and Sections.

Section through Mount Royal along the line of the Canadian Northern Railway tunnel.....	36
Diagrammatic section through Mount Johnson showing the relations of the several rocks types.....	63
Section in the Pre-Cambrian at Papineauville, Que., on north side of railroad.....	94
Radially arranged phlogopite rim between graphitic pegmatite and Grenville limestone, Walker mine.....	104

Photographs.

Contact of the anorthosite and Laurentian limestone. From about 1 miles N.W. of St. Sauveur, P.Q.....	4
Boulder of anorthosite, range IX., lot 5, Chertsey, P.Q. Shows the segregation of the Mg-Fe. minerals into certain portions of the rock.....	11
Microphotographs showing the progressive granulation of the Morin anorthosite under the influence of pressure.....	13
Cliffs of massive anorthosite in railway cutting a mile and a quarter northwest of Ste. Marguérite.....	21
Anorthosite from New Glasgow, P.Q. Microphotograph between crosses nicols.....	23
Exposures of white anorthosite. Falls of the river L'Achigan, New Glasgow, P.Q.....	26
View of the Monteregian Hills from Mount Royal. In the foreground the city of Montreal. In the middle distance the River St. Lawrence with St. Helen's island. (Reproduced with the permission of Messrs. William Notman & Son).....	31
View of Mount Royal from the south. (Reproduced with the permission of Messrs. William Notman & Son).....	

PAGE.

Breccia with camptonite matrix. Rockland avenue, Outremont, Montreal 35
Dykes cutting the Trenton limestone. Westmount Reservoir quarry, Montreal 43
Microphotograph of alnoite. Point St. Charles, Montreal. The lath-shaped crystals are melilite showing peg structure. 48
Contact of nepheline syenite (on left) with Trenton limestone (on right). The limestone is highly altered. Both rocks are cut by numerous dykes. Corporation quarry, Outremont, Montreal 52
Tinguaite sheet, with Trenton limestone above and below, forming the floor of the quarry. Quarry at the head of Delorimier avenue, Montreal 54
Mount Johnson as seen from the southwest, showing the limits of the several rock types composing the mountain 62
Andose in quarry on Mount Johnson, showing vertical flow structure 76
Quarry in andose, Mount Johnson, showing vertical flow structure (on right) 78
Côte St. Pierre. Eozoon locality to left of picture 96
Columnar graphite and altered Grenville limestone, Walker mine (Nelly's pits) 102
Mica (phlogopite) with pyroxene (P), apatite (A) and calcite. Vein matter, Nellis mine 112

Pocket contains 5 items

A7 and 10



Legend

- Dykes of various petrographical types
- Bostonite breccia. U. Altered Utica in breccia
- Bostonite sheet
- Camptonite sheet
- Outremont breccia
- St Helen I. breccia. D. Inclusions of devonian
- Fourchite sheet
- Tinguaite sheet. F. Feeder of Tinguaite sheet
- Westmount breccia. U. Utica inclusions
- Intrusive contact
- Nepheline syenite. E. Epidote bearing. U. Inclusions of Utica
- Quartzite-olivine essexite breccia
- Essexite, brecciated
- Essexite olivine-bearing
- Essexite normal. E. Epidote bearing. O. Olivine bearing
- Altered Utica
- Utica
- Marmorized Trenton. M. With minerals of contact metamorphism
- Trenton
- Chazy

Ordovician

- Horizontal strata
- Dip and strike

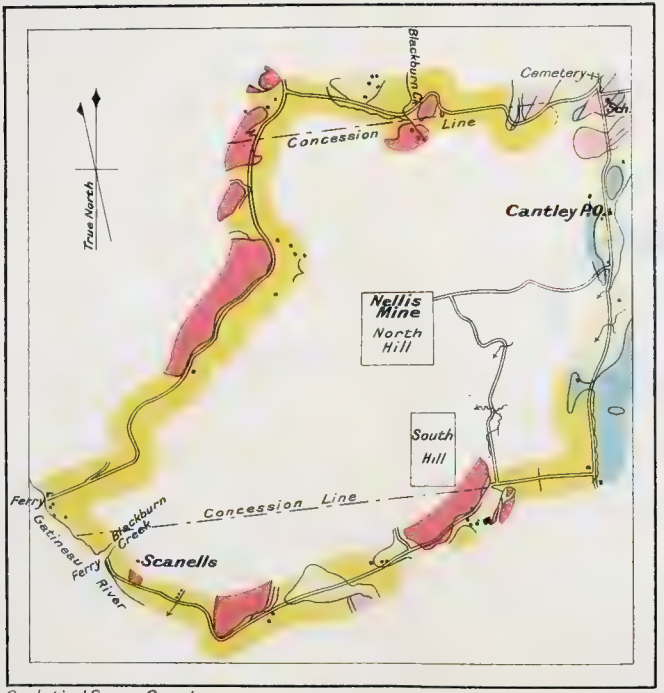
Geological Survey, Canada.

Montreal

Miles 0 ¼ ½ ¾ 1

Kilometres 0 1 2

A.8.



Legend

Post-Glacial
- Saxicava sand
- Leda clay

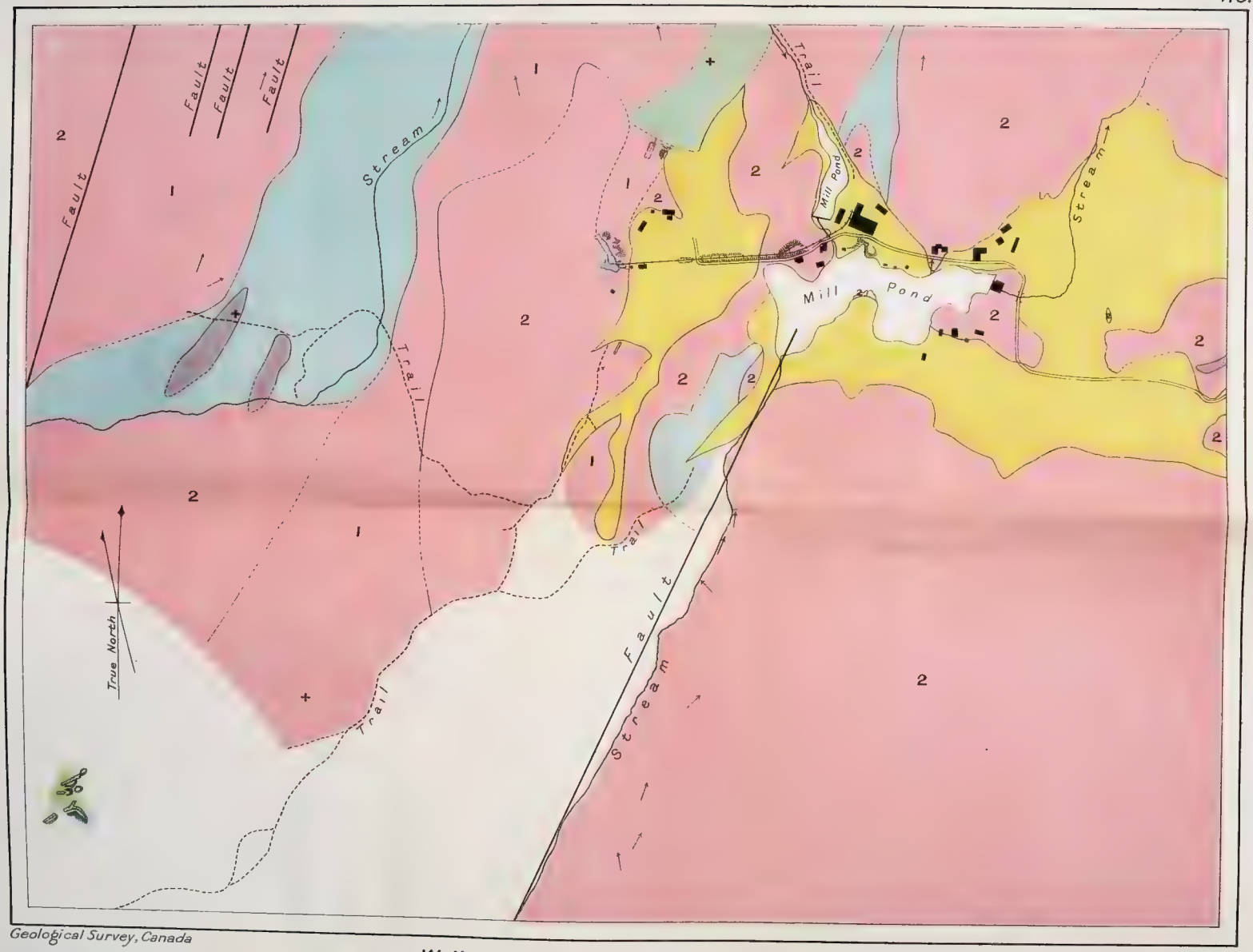
Pre-Cambrian
- Binary granite
- Diorite
- Granite
- Limestone
- Quartzite, etc

Geological Survey, Canada

Route map, **Cantley, Quebec.**

Feet
1000 0 2000 4000

Metres
500 0 1000



Legend

- Post-Glacial — Leda clay
- Pre-Cambrian
 - Pegmatite
 - Anorthosite
 - Gabbro
 - 1-2
 - 2. Uttawa gneiss, gabbro etc.
 - 1. Quartz-pyroxene gneiss
 - Grenville limestone
- Graphite ore-body
- Tongue of gabbro pegmatite

Geological Survey, Canada

Walker Mine, Buckingham Township, Quebec.

Feet: 500, 400, 300, 200, 100, 0, 500, 1000

Metres: 100, 50, 0, 250



Legend

Post-Glacial
- Saxicava sand
- Leda clay

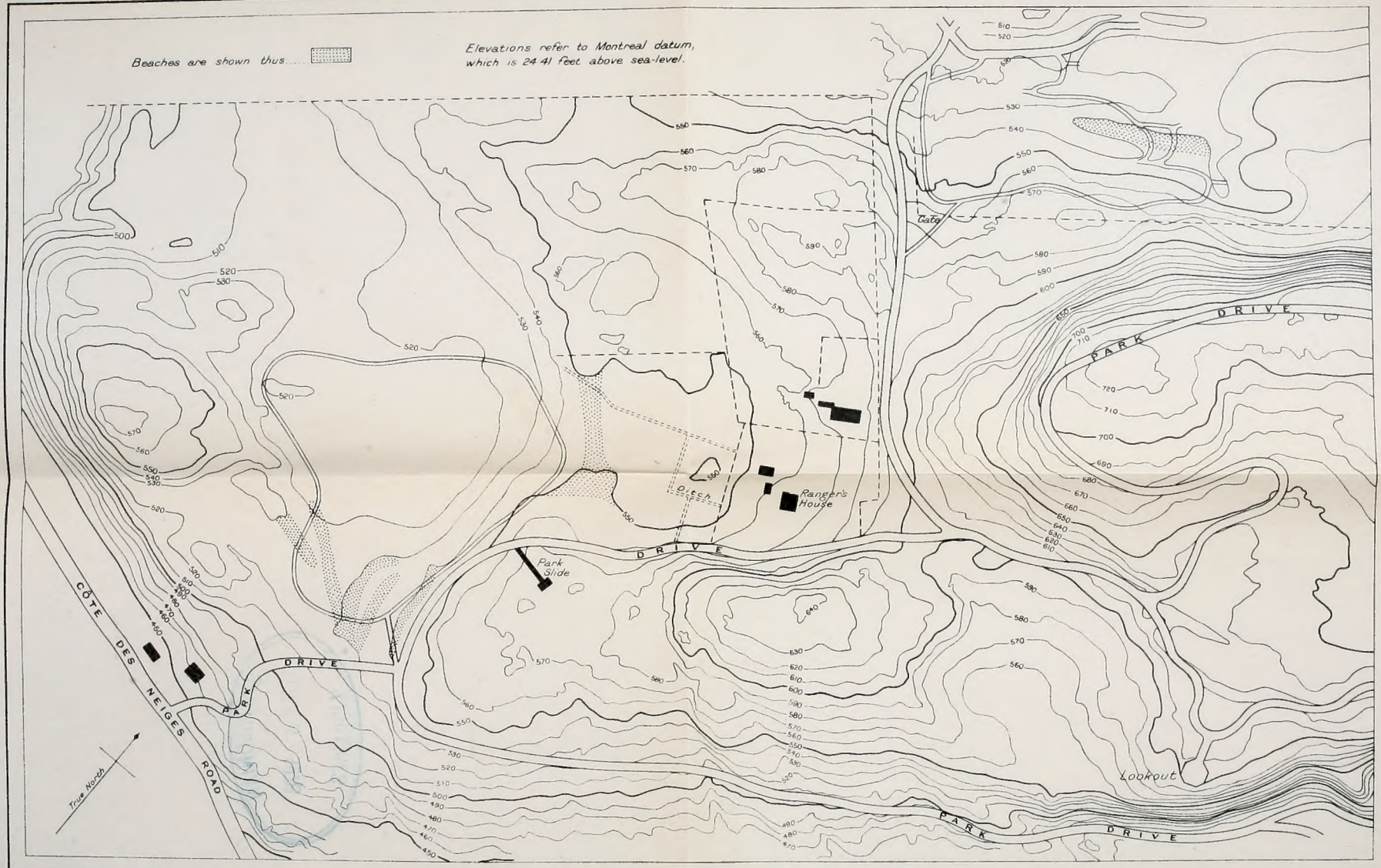
Pre-Cambrian
- "Blue-quartz" veins
- Gabbro
- Pegmatite
- Ottawa gneiss
- Grenville limestone
- Grenville series other than limestone

Geological Survey, Canada

Route map between **Buckingham** and **Emerald Mine**

Feet
1000 0 4000 8000 12000

Metres
1000 0 2000



Geological Survey, Canada.

Base-map from manuscript in the office of the City Surveyor, Montreal.

Part of Mount Royal showing Upper Marine Beaches

Feet
200 100 0 200 400 600 800

Metres
100 50 0 100 200 300 400

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